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ABSTRACT

This document is the third of a three-volume teacher resource book for use with the Energy 80 energy education program. The program is designed to enhance students' understanding of energy, either through supplements to traditional courses, such as mathematics, science, social studies, or homemaking, or by developing a mini-course or interdisciplinary course in energy. Although written for middle/junior high school students, many of the activities are useful for high school and upper elementary grades. Included are 15 activity sheets, 14 worksheets, 32 readings and 18 overhead transparency masters for use with units on: (1) the history and technology of fossil fuels; (2) energy from nuclear fission; (3) renewable energy sources; (4) energy in the United States; (5) economics and decision-making; and (6) energy conservation. Also included with each unit is an overview and lesson plans for each activity/topic. Provided with lesson plans, are objectives, lesson format, materials needed, background information, and instructional strategies. (JN)

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TEACHING VOL. 3
ABOUT ENERGY

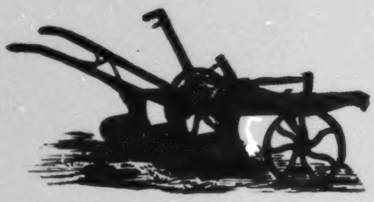
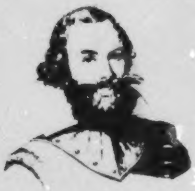
1983

Units 3 through 8 of the **Energy 80** Resource Book

Enterprise for Education, Inc.
Santa Monica, California

3. Fossil Fuels:
   History & Technology
4. Energy from Nuclear Fission
5. Renewable Energy Sources
6. Energy in the United States
7. Economics & Decision-Making
8. Conservation

173 pages of Reproducibles:
15 activity sheets
14 worksheets
32 readings
18 overheads

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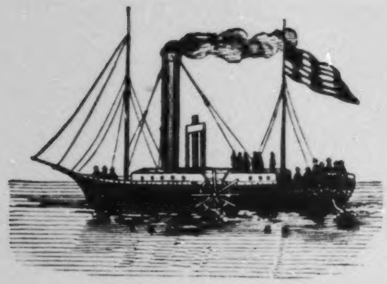
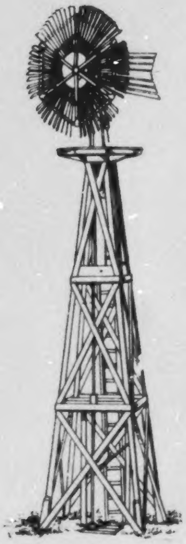
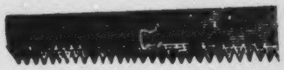
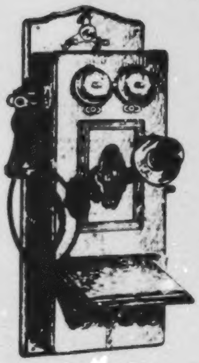

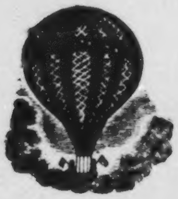

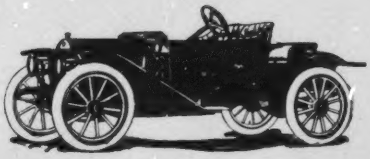

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TEACHING ABOUT ENERGY

VOL. 3

Units Three through Eight

1983

The Energy 80 Resource Book

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Unit One
Energy Fundamentals

Unit Two
Energy Flows in Nature

will be found in Volume 2

Unit Three
Fossil Fuels History & Technology

People and fuel
Coal
Oil
Natural Gas

Unit Four
Energy from Nuclear Fission

Unit Five
Renewable Energy Sources

Thermal energy from sunlight
The sun's apparent movement
Concentrating collectors
Biomass

Unit Six
Energy in the United States

How Americans in earlier times used energy
Energy use in the U.S. today

Unit Seven
Economics and Decision-Making

Economics: scarcity of useful energy
Economics of energy supply
Economics of energy conservation

Unit Eight
Conservation

Unit Three
Fossil Fuels
History & Technology

Narrative Overview

Why We're Teaching This

Our present standards of living rest on a rate of energy consumption unique in history, a rate made possible by a long string of technological changes. Probably the innovations that have had the greatest effect on our lives have concerned the use of fossil fuels. Today, the fossil fuels are by far the largest source of energy for industrial societies.

Our dependence on fossil fuels is expected to continue throughout the lifetimes of today's students. An understanding of the various fossil fuels—how they differ, the ways we have used them and might use them in the future, the implications of their use—is basic to students' understanding of our present energy situation, and even of our society.

The geological facts alone assure that our present situation cannot continue indefinitely. Further changes are inevitable. To be prepared to help in creating and carrying out constructive changes, students need to gain an insight into the role of technological innovation in energy use, and of energy use in human welfare.

In this unit we want to give students:

- some historical perspective on humankind's use of fuel
- an appreciation of the value of fuel to the production, not just of heat for comfort or cooking, but also of raw materials like pottery and steel and of mechanical energy
- an appreciation of the differing characteristics of the fossil fuels, and how these characteristics have contributed to our society's transition from one primary fuel to another
- an appreciation of the ability of humans to change the way they use our planet's resources
- an appreciation of the impact fuel use can have on the environment

What We'll Teach and How

This is inevitably an interdisciplinary unit. Individual lessons often mix "science labs" with other activities typical of social studies.

1. Why are fuels important to people?

The evolution of human use of fuel is treated chronologically. After speculating on the importance of fire to the caveman, students replicate the ancient Egyptians' use of fuels to fire pottery and to smelt copper from an ore. Performing these activities not only acquaints students with some basic principles of raw material production, which have not changed in 3000 years, but it also dramatizes the accomplishments of ancient civilizations and emphasizes the rapidity of change in the last few centuries. Finally, they review how more than 2000 years after the Egyptians, the English succeeded in producing mechanical energy from a fuel. In addition to the activities, a small number of primary source material readings are provided in this section.

2. How do the fossil fuels differ, and how has that affected human use of them?

a. Coal. Students do a lab activity comparing burning wood and burning coal, and study a reading from the beginning of the transition to coal in wood-burning medieval England. Present-day mining and transportation of coal are presented; it is suggested films be used in doing this if they are available. The concept of a "fuel cycle" is introduced, and students review the coal fuel cycle.

As a transition from coal to other fossil fuels, students think about the human need for light, and use fuels to make light, making candles and oil lamps. Coal gas may be produced in a teacher demonstration.

b. Oil. Originally extracted to fuel lamps, oil use has boomed because its unique nature has allowed a huge return of energy for relatively little investment. The development of petroleum from organic deposits, oil exploration, the chemical nature of oil, and oil refining are presented through investigations, simulations, paper-and-pencil activities, films if available, and teacher demonstrations. Mixed with these more technical topics are readings of historical primary source materials, used to show how such demands as people's need for light, or transportation, have changed crude oil extraction and use over the course of a century. (The impact of oil and the internal combustion engine on society are treated in Unit 6.)

c. Natural gas. Students compare coal to gas as a residential fuel through activities which use household manuals and advertisements of the late 1800s to compare their convenience. The growth of the pipeline network in extending the market for gas is examined. The potential of liquified natural gas, and its potential problems, are treated in a lesson based on a teacher demonstration.

d. Finally, we compare the three fossil fuels named above, to see how their physical characteristics have affected the history of their use. Such a discussion always reveals coal's relative abundance as well as the problem of pollution from burning it, so we then look at some ways of cleaning up coal.

3. What is the outlook for the fossil fuels?

a. Resource depletion. Students become acquainted with the problem of resource depletion through a simulation activity and through discussion of historical data on production from a few specific deposits. We consider how changes in technology may provide new fuel resources, like oil shale or tar sands; more efficient extraction through enhanced recovery from deposits now being worked, and more make possible more efficient use of what is extracted.

b. Pollution. Reviewing pollution control measures discussed earlier, we look beyond them to give a brief introduction to thermal pollution and the carbon dioxide problem.

People and Fuel

Objectives

This lesson contributes to students' understanding of the following concepts:

Prehistoric people used fuel for warmth and cooking.

By the time of the Romans, fuel was used to extract raw materials and manufacture things.

Today we use fuel for earlier purposes, and also to get mechanical power.

Format of the Lesson

Discuss "cavepeople's" use of fire

Read Pliny aloud in class

Discuss use of fire 2000 years ago

Discuss fire today

Distribute homework sheet

Materials Needed

list of fuel sources used by local utility. Get this information by phoning them.

chalkboard

Preliminary Discussion

Develop students' ideas about early men, "cavemen." Ask how they got their food. Ask what use students think cavepeople made of fire. List these uses on the chalkboard. How might they have started fires? What do you need to have a fire? Stress to the class the necessity of having something to burn. (Define fuel as something to be burnt.)

If you have completed the previous unit, including the origin of fossil fuel, the discussion of fuel can be brief.

By the Time of Ancient Rome

Go over the chalkboard list of the uses the students have suggested that cavepeople might have made of fire. Point out that even today there are primitive people who use fire for only these uses. (The Tasaday in the Philippines.) But by the time of ancient Greece and Rome people had learned many other uses for fuel.

Help the class to recall what they know of Greek and Roman times. Then read the selection from Pliny aloud.

> We cannot but marvel at the fact that fire is necessary for almost every operation. It takes the sands of the earth and melts them, now into glass, now into silver, or minium, or one or other lead, or some substance useful to the painter or the physician. By fire minerals are disintegrated and copper produced: in fire iron is born, and by fire it is subdued: by fire gold is purified: by fire stones are burned for the binding together or walls of houses . . . It is only when ignited and quenched that charcoal itself acquires its characteristic powers, and only when it seems to have perished that it becomes endowed with greater virtue.
>
> Pliny the Elder, *Natural History*, Vol. XXXVI (Pliny died in the volcanic eruption that buried Pompeii in 79 AD).

Explicating Pliny

Many classes can figure out what Pliny is talking about without prompting. It isn't necessary that every word be clear, but that the general idea of extending the use of fuels to the production of raw materials be clear. For your information only, some comments on Pliny:

"glass" is made from sand heated with other substances

"minium" = red lead, lead oxide used as a paint pigment

"minerals are disintegrated and copper produced" = smelting of copper ore

"iron is born" = smelting

"subdued" = tempering of iron, a way of altering its hardness

"gold is purified" = refining

"stones are burned" = making lime by heating limestone. Lime is used for mortar. Portland cement is made by a similar process.

"charcoal ignited" = pyrolysis of wood

Make a list of the uses Pliny mentions. What uses for fire does Pliny mention that cavepeople would not have known of?

Make the point that we use fire for all the uses the caveman did, and all the uses the Greeks did, and we have added some of our own. And there has been another very significant change: we use fossil fuels.

Pass our the worksheet **Fuels in Your Life.**

Go over the worksheet to be certain students understand how to complete it, and supply the data needed on fuels burned by the local power company.

Projects for Independent Investigation

1. Read the Greek myth of Prometheus. Tell the story to the class. What did Prometheus do? Why did the gods think his action was so important? What does this myth tell us about the importance of fire to the ancient Greeks?
2. Make a timeline as a wall poster, starting at 2000 B.C. and going to 2000 A.D. Mark important changes in people's use of energy on the timeline as you learn about them.
3. If you don't already have fire, how can you make it? Demonstrate for the class how people could start fires from friction (boy scout rubbing two sticks together) or flint and steel.

Fuels In Your Life

Fill in the blanks below by writing the name of the fuel you use to do the job.

You may use electricity to do some of the jobs. Your teacher will tell you what the power company in your community uses to generate the electricity it sells. Write the percentages down:

Non-fuel sources:

hydropower: ________%
geothermal: ________%
windpower: ________%
nuclear: ________%

From burning fuels:

natural gas: ________%
petroleum: ________%
coal: ________%
wood + wastes: ______%

If you use only electricity for one of the jobs below and none of your city's electricity comes from burning fuels, write "nothing" in the blank, Otherwise, write the names of the fuels the company uses.

1. To keep my home warm, we burn ______________________________.
2. To make our car move, we burn ______________________________.
3. To plow the fields and plant the food I eat, the farmer burned ______________________________.
4. To warm water at our house, we burn ______________________________.
5. To cook our food, we burn ______________________________.
6. To clean our clothes, we burn ______________________________.
7. To light our house, we burn ______________________________.
8. To make the iron in our automobile, the steel company burned ______________________________.

A. Which of the uses above would a caveperson have understood? Numbers: ______________________________.

B. Which of the uses above would Pliny have understood? Numbers: ______________________________.

C. Which uses are unlike any Pliny would have known of? Numbers: ______________________________.

D. Of the fuels listed, which do you guess might have been familiar to the caveperson? ______________.

E. Of the fuels listed, which do you guess might have been familiar to Pliny? ______________________________.

Answers to the Worksheet Fuels in Your Life

If you are unable to obtain from your local utility its "fuel mix," you may use the 1981 national average figures, listed below. In giving these figures to your students, caution them that the situation may be very different from region to region. Some states get over half their electrical energy from nuclear energy, others none; in some hydroelectric power is a major source, in others it is insignificant; and so on.

Non-Fuels: 24%
hydropower: 11%
geothermal: less than 1%
windpower: less than 1%
nuclear: 12%

Fuels: 76%
natural gas: 15%
oil: 9%
coal: 52%
wood and wastes: less than 1%

1. The answer depends on the student's home heating system. If the system is electrical, the fuels listed should be those used by the local electric utility. Otherwise, the answer will be natural gas or fuel oil, or in a very few cases wood, propane, or kerosene.

2. The energy to move cars comes from gasoline or diesel oil, which are petroleum products.

3. Farm tractors use diesel fuel and gasoline, which are petroleum products.

4. The answer depends on the water heating system in the student's home. If the system is electrical, the fuels listed should be those used by the local electric utility. Otherwise, the answer will be natural gas or in a few cases fuel oil, propane (which are petroleum products), or wood.

5. The answer depends on the stove in the student's home. If an electric stove is used, the fuels listed should be those used by the local electric utility. Otherwise, the answer will be natural gas or in a very few cases, wood, kerosene, or propane (the last two being petroleum products).

6. To clean our clothes we heat water and use electricity to operate a washing machine. Therefore we need the energy source which is the answer to question 4, and also whatever fuels are burned by the electric utility.

7. Since almost all lighting is now electric, the answer would be whatever fuels are burned by the utility. For esthetic reasons, some households on occasion also use candles and oil lamps.

8. Coal. Increasingly, steel is being made electrically, but most of this electricity is generated by burning coal.

A. The caveperson would have been familiar with using fuel for 1 (home heating), maybe 4 (water heating), 5 (cooking) and 7 (lighting).

B. In addition to 1, 5, and 7, Pliny definitely would have understood 4 (water heating) and 8 (using fuel to get metal from ore).

C. 2 and 3. The big breakthrough between our time and Pliny's was the discovery of ways of using fuels to do work. Not listed in the worksheet is the momentous recent discovery of a way to use energy, often from fuels, to do "thinking" work.

D. The caveperson would have known wood as a fuel.

E. Pliny would also have known of wood. No other fuels were widely used, although there is evidence that Pliny might have known about natural gas and oil.

Wood or Coal?

Note: You will need to do part of this lesson out-of-doors, because of the smoke produced.

Objectives

This lesson contributes to students' understanding of the following concepts:

There are different kinds of coal.

Coal produces undesirable by-products when it burns.

People knew of coal for hundreds of years before extensive use was made of it.

Format of the Lesson

Handling of coal samples

Burning of wood and coal

Discussion of English coal laws

Materials Needed

coal sample Purchase from a local coal dealer or from a mineral supply house such as Wards. One hundred pounds of blacksmith coal costs about $8.00; share with other schools.

hot plate hibachi, or similar grill. This will be used to ignite the samples. If an electric hot plate is used, provide a heavy extension cord to reach outdoors. If you use a charcoal grill, light it far enough in advance that it produces no flame or smoke to confuse observations.

scale a simple balance will do. Devising such a balance can be an exercise for a group of students.

wood a piece of scrap lumber the same weight as a piece of coal you have.

reading **A Royal Proclamation,** one for each student

Preliminary Discussion

If you are using a charcoal grill, preheat it prior to the discussion. Pass around the coal samples. Select a piece of bituminous coal about as large as a walnut. Select a piece of wood of approximatly equal weight. Ask students when they think people first used coal as fuel.

Some examples:

Chinese at least 100 B.C., some believe 1000 B.C.

Medieval Europe 1200 A.D. (blacksmiths)

Hopi Indians 1200 A.D.

So by the early Middle Ages Europeans knew about coal.

But most people burned wood or charcoal – as many people still do.

Why did people burn wood instead of coal? Let's make some observations.

Pass out the observation worksheet (or put the questions on the chalkboard for copying) and take the class outside.

Experiment

Counsel the students to observe the burning closely. Place the wood on the hotplate or the iron grill of the hibachi. Observe the burning. Repeat with coal. Remove the ash for examination. Secure the safety of the site and return to the classroom.

Discussion

Compare observations. Students will have noted the more objectionable air pollution from coal.

Confirm that most people did not regard coal as the ideal fuel, compared with wood.

A Royal Proclamation of 1307

On June 12, 1307, King Edward I of England sent the following message to the Sheriff of Surrey, to be proclaimed. A proclamation like this was read aloud in the marketplace and other public meeting places. "Sea-coal" is what coal was called in those days. "Prelates" are clergymen; in those days much of England was owned by religious orders. "Magnates" are public officials. Look up "forfeiture" in the dictionary. Read the proclamation, and then answer the questions on a separate sheet of paper.

Of Surrey. Order to cause proclamation to be made in the town of Southwark that all who wish to use kilns in that town or its confines, shall make their kilns of brushwood or charcoal in the usual way, and shall not use in any way sea-coal hereafter, under pain of heavy forfeiture, and the sheriff shall cause this order to be observed inviolably hereafter, as the King learns from the complaint of prelates and magnates of his realm, who frequently come to London for the benefit of the commonwealth by his order, and from the complaint of his citizens and all his people dwelling there and in Southwark that the workmen in the city and town aforesaid and in their confines now burn them and construct them of sea-coal instead of brushwood or charcoal, from the use of which sea-coal an intolerable smell diffuses itself throughout the neighboring places and the air is greatly infected, to the annoyance of the magnates, citizens and others there dwelling and to the injury of their bodily health.

The like to the mayor and sheriffs of London.

1. The King says two different groups of people have been complaining to him: visitors to Southwark (the "prelates and magnates") and citizens. Which group do you think was most likely to have the King's ear?
2. Why were people objecting to the burning of coal?
3. Do you have any laws in your community that are like the King's proclamation? What actions do they forbid? Who makes the laws?
4. What was "the usual way"?
5. Do you think everyone in Southwark was happy about this proclamation? Why not?
6. Should the government pass laws to prevent "annoyance" and to prevent "the injury of bodily health?"

For Further Research

The city of Southwark became part of London a few decades after this proclamation. Find out what connections Southwark had with the writers Chaucer and Shakespeare. What connections does Southwark have with American history?

Comparing Burning Wood and Coal

Observe the burning of equal weights of coal and wood. Then answer the following questions:

1. Describe the appearance of the smoke each produced.

2. Describe the smell.

3. Do you think heat boiled gases out of the wood? Record observations to support your view.

4. Do you think heat boiled gases out of the coal? Record observations.

5. Which burned longest?

6. Which seemed to give off more heat in burning?

Wells

Objectives

This lesson contributes to students' understanding of the following concepts:

Some rocks are porous and can hold liquids in those pores.

Water can pass through some kinds of rocks but not through others.

Holes can be drilled through solid rock.

In the early days of the United States, salt water was a valuable substance obtained from wells, though it was often contaminated with oil.

Format of the Lesson

Discussion: wells for water

Demonstration: water in rock

Demonstration: percussion drilling

Teacher narrative of start of oil industry

Demonstration: kerosene lantern

Homework assignment

Materials Needed

coarse sandstone specimen hand size.

specimen of any impermeable rock such as granite, gneiss, or most shales.

water

*star drill**

*sledge hammer**

*goggles**

*a rock or brick**

overhead transparency **Percussion Drill.**

kerosene lantern

*How you teach this lesson depends on your access to some common tools used to drill holes in concrete or brick walls and floors. If you aren't familiar with these tools and don't have them at home, you can probably borrow them from the school custodian or the industrial arts teacher. Better yet, let her or one of her students come to demonstrate their use.

Preliminary Discussion

One of the things everyone needs, even more than artifical light, is water. How do people get water? Pursue the question until someone suggests wells, or digging holes in the ground.

What do you run into as you dig? (ANS: First soil and then, eventually, solid rock.)

When you reach solid rock (it's called bedrock) is there any point in going farther? (ANS: Yes, people do bore water wells beyond the soil.)

Demonstrate Porosity of Some Rock

Confirm that we do drill water wells into rocks because we often find layers of rocks holding water.

Take out the sandstone specimen and sprinkle water on it. The water will be absorbed (more quickly on some sandstones than others; check yours in advance). Let the students try this for themselves. Observe that the same thing happens when we wet concrete or plaster. Where did the water go? (We will answer this question in the next lesson.)

Now try sprinkling water on an impermeable rock. It sits on the surface, just as it would had it been sprinkled on a piece of metal. So rocks differ in whether they can hold water or not.

Because some rock layers can hold water (they are called aquifers), there is a value in being able to drill a well into solid rock. The Chinese invented ways of doing this 2,600 years ago. Let's see one way a hole can be drilled into rock.

Demonstrate Percussion Drilling

Explain to the students that we're going to make a small hole in a rock the same way people drill some wells.

The star drill is used by placing the cutting edge on the rock and striking the drill with a sledge hammer weighing at least two pounds. Nail hammers won't work. After each blow, the drill is rotated slightly to expose fresh rock to the cutting edges.

Flying rock (and sometimes metal) chips are produced, so the user **must wear eye protection.** You may want to use a clean plastic safety shield. Don't permit students to stand too close to the rock as it is being drilled.

Pass the rock around and let students examine the hole. Explain that this is how early well drilling was done. Project the overhead of the drawing and discuss how the drill worked.

This method of drilling shallow wells is still in use. Powered equipment is used to raise and lower the bit. But the Chinese (who invented this method of drilling about 600 BC) were still doing it entirely by hand as late as the Second World War. To drill a gas well to 4,000 feet took them four years and four months.

What do you think the ancient Chinese, and the Americans in the early 1800s, were most often looking for when they drilled wells?

Salt

They were looking for salt water, because without refrigeration they needed salt to preserve meat.

Drilling wells for salt water gave people experience in drilling wells.

However, they were often frustrated because the salt water they got was contaminated with petroleum.

Rock Oil

Explain that people have been using petroleum since the days of ancient Mesopotamia. In many places it seeps to the surface naturally. It was used to caulk boats, for example. But these were minor uses and there was not a great demand for petroleum.

A druggist in Pittsburgh owned some brine wells that produced a lot of useless petroleum. He got the idea of distilling the petroleum to convert it into lamp oil, for which there was great demand. But the resulting lamp oil gave off a bad smell and heavy black smoke.

Other people were making lamp oil by distilling coal and shale, somewhat as we did in a previous lesson. One brand of this oil from coal was called "kerosene," By 1840, there were about 50 coal oil plants making about 23,000 gallons of lamp oil a year, mostly from coal.

Some of these coal oil manufacturers ran "rock oil" through their distilleries. It produced a superior lamp oil.

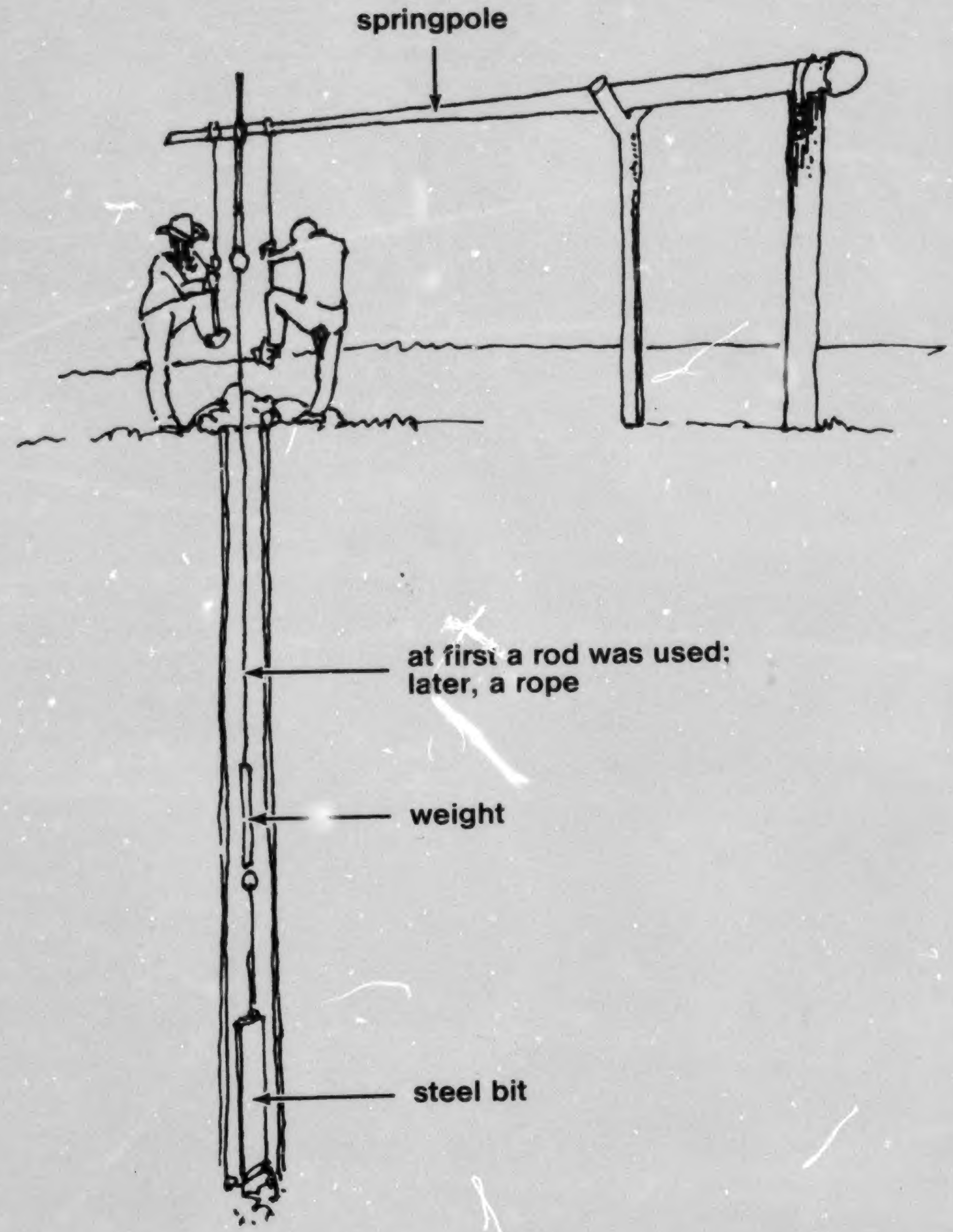
One company decided to try to use salt water well-drilling techniques to get oil. They sent a man named Edwin Drake to a place in Pennsylvania where oil was often found seeping to the surface, and he hired some men who were experienced in drilling salt water wells. On August 27, 1859, at a depth of 69½ feet, the first oil well came in!

There was soon a boom, with wells and distilleries all over the area. The product eventually got the name kerosene, from the brand name that had been used for one brand of coal oil. And why did people want this kerosene? (ANS: They wanted it for their lamps.)

(Light the kerosene lantern.) Right, that's what they wanted. This is how the whole oil industry got started, to make kerosene. In a few years people were burning American kerosene in lamps from China to Peru. Of course, the distilleries also produced a lot of useless by-products that the distillers just threw away, like gasoline!

Additional Activities

1. If there are any in your area, visit a working oil well.
2. Show the film, **Oil Well** (available on free loan from Shell Oil Company; 21 minutes, color). Exploratory drilling, both on- and off-shore. Helpful animation. Unfortunately, the vocabulary level is a bit too high to be entirely comfortable for middle school use. Nevertheless, recommended.


springpole
at first a rod was used; later, a rope
weight
steel bit

Coal or Gas?

Objectives

This lesson contributes to students' understanding of the following concepts:

In comparison with earlier fuels, such as coal and wood, little equipment or effort by the consumer is needed to burn gas.

Household use of gas had begun by the end of the 19th Century.

Format of the Lesson

This lesson takes two days, separated by a homework assignment.

Discuss need for stoves in households

Describe activity

Assign readings

Mime starting of stoves

Compare household use of coal and gas

Materials Needed

reading **Starting a Coal Stove,** enough copies to provide one copy each for about three-quarters of the class.

reading **Starting a Gas Stove,** one copy for each of the rest of the class.

overhead **The Coal Stove.**

FIRST DAY

Preliminary Discussion

Direct the attention of the class to the role stoves play in everyone's life. One of the jobs that is done in almost every household is cooking food. To do this, people use fuel. The early settlers of North America cooked their food in their wood-burning fireplaces. By 1900, most American families used some sort of stove. Of course, they were not like the stoves we have in our homes today.

Setting Up the Activity

Ask the students to pretend they are living in the early 1900s. Tell them they are going to act out how they think people at that time would have used their stoves.

Ask the students if they know what mime is. Many may have seen a mime on television. A mime is a kind of silent actor. Mimes often pretend to be using things that aren't really there. Ask for a volunteer to mime cooking an egg on the family stove. While the volunteer does this, ask individual students to describe what the mime is doing.

Tell the class that we will act out what we would have to do using two different stoves, both of which were in use at the beginning of the century. You will give them some reading material that describes how to work the stoves. Then, tomorrow, you will call on different people to do various parts of the job.

Pass out the two readings, distributing them randomly around the class. Consider preparing a cassette for the listening center, if appropriate for your students.

SECOND DAY

The Coal Stove

Put on the transparency of the coal stove. Ask for a volunteer to act out preparing kindling for the stove, and another volunteer to describe what the person is doing.

Then follow through by assigning the jobs listed below, one by one. Assign an interpreter for each job, too. Allow students to refer to their readings while watching the acting-out. After the mime finishes, ask students if the job was properly done.

bring coal up from the basement

clean out the old ashes

lay the fire

polish the stove

add the coal

the fire goes out; what do you do now?

remove the coal

clean the stove

lay the fire

add the coal

the blue flame is gone; what do you do now?

it's burning freely; now what?

The Gas Stove

Repeat the activity with the gas stove. Only one mime and interpreter will be needed because of the ease of starting the stove.

Post-Activity Discussion

Which was easier to use, the coal stove or the gas stove?

Knowing the burden on the person using and caring for the stove doesn't tell the whole story. To make a good comparison, we need to consider the whole system. The system would include the difficulty and expense of manufacturing the stove and the other equipment needed to bring fuel to the stove, the labor of other workers, like the coal-delivery man, and so forth, all so the stove could be used to cook somebody's breakfast. Tell the class you want them to make a more detailed comparison, and in their comparisons they should try to discuss the other parts of the system, too.

Compare how hard it was to get fuel to the two stoves.

Compare how hard it was to dispose of the ashes from the two stoves.

Compare how hard it was to start the fires or regulate the amounts of heat produced.

Compare the air pollution the fires in the two stoves produced and what was done to get it out of the house.

Are there any other difficulties we haven't discussed?

Which is the simpler and cheaper stove? Why?

How does each stove depend on the help of other people? What jobs and equipment would be involved in supplying the coal? The gas?

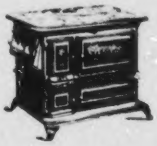
What do you think happened to coal stove sales as more and more homes were connected to gas mains?

Have you ever heard the expression, "Now you're cooking with gas!"? What does it mean? Where do you think it came from?

Summarize that by 1900 it was evident to many people that gas was a clean-burning, easy-to-use fuel. The transition from coal to gas as a household fuel had begun.

Starting a Coal Stove

In the 1890s, many American homes used coal stoves like the one pictured below Here are instructions for starting a coal stove, from the **Boston Cooking School Text Book,** by Mrs. D.A. Lincoln, published in 1887.



Remove the covers on the top of the stove and brush the ashes from inside the stove into the firebox. Replace the covers, close the dampers and turn over the grate. Shake the lower grate, letting the ashes sift into the ash-pan; when the dust ceases to rise, brush out the oven, remove the cinders from the lower grate and reserve them to burn again. When taken out in this way, the ashes in the pan will not require sifting.

If there be no lower grate, remove the ashes and cinders together and sift them; pick over the cinders carefully, and throw out stones and clinkers. These should never be burned as they injure the lining of the fire box; but any pieces of half-burned coal, should be saved. Always take out the ashes before lighting the fire, for if they are left in the pan, sparks and lighted coals will drop into them; it is then highly imprudent to remove them, unless they are placed in a fireproof ash receiver. Fires have been occasioned by careless storing of hot ashes.

Put into the firebox, first, shavings or loosely wadded newspapers, letting them come close to the front; next, arrange fine pine kindlings crosswise and so that the air may circulate freely between the pieces; be careful to have the kindling touch the ends and sides of the firebox so that coal may not drop through to the grate. Then put on enough hard-wood, arranged in the same manner as the kindling, to come near the top of the firebox, put on the covers, open the dampers, and brush the dust off the stove.

Moisten some stove polish with cold water, and put it on the stove with the dauber; rub the blacking in thoroughly. Next light the shavings and paper in the firebox from below the grate, and while the fire is kindling, polish the stove with the dry polishing brush. Remember, blacken the stove while it is cold, but work up the polish as it begins to heat.

When the wood is well kindled, put in a few more pieces of hard-wood, and press the coals down to the grate. Next put on coal enough to cover the wood and when this has kindled, fill the firebox to the top of the lining. By making sure that the hard-wood kindles first, and adding the coal gradually, much trouble is saved; for, unless the kindling be well seasoned, and part of it hard-wood, and plenty of it used, it will either not kindle or it will burn out before the coal is ignited. In that case, the coal must be removed and the fire rebuilt from the start. The blazing heat from the wood alone warms the stoves and the oven quickly becomes hot.

When the blue flame is no longer seen (on the coals) close the oven damper; and as soon as the coal is burning freely, shut the front damper; then regulate the fire by the slide or the damper in the pipe. While starting and watching the fire, empty the teakettle, wipe the inside, fill it and the reservoir with fresh water — never from the hot water tank — finish polishing the sides and back of the range and brush up the floor and hearth.

Using a Gas Stove

GAS COOKING WITH ECONOMY.

JOHN R. SHIRLEY,
Inventor and Manufacturer of
SHIRLEY'S NEW GAS STOVES and OVENS,
Cor. Pine and Eddy Sts.. Providence, R. I.

——:o:——

In introducing to the public Shirley's New Gas Cooking Stoves and Ovens, we desire to call attention to the comfort and convenience of cooking by gas, especially during the summer months when a fire is not required for other purposes. The advantages derived by the use of gas as a fuel for cooking can only be fully appreciated by those who have had experience in its extremely useful application for that purpose, but to obtain all the advantages, one must be careful to select a stove so constructed as to develop and utilize the greatest heat obtainable from a given quantity of gas.

In the construction of these stoves, great care has been taken that the gas should be so applied as to ensure perfect combustion and the smallest amount of consumption practical. That it generates and completely utilizes heat in large quantities compared with the quantity of gas consumed, is abundantly proven by the fact that it will roast a joint of meat weighing seven or eight pounds for the trifling sum of three cents.

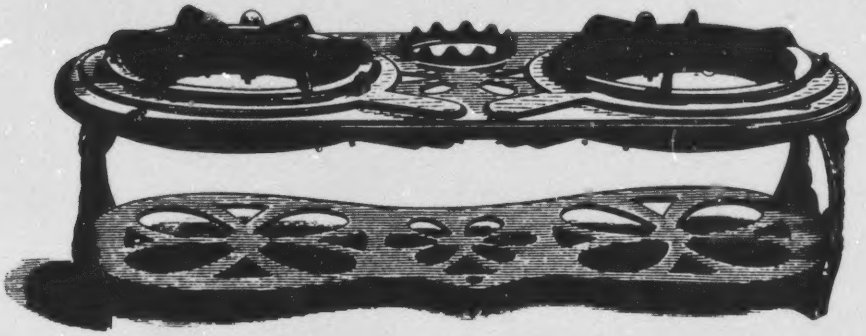
To obtain a perfect estimate of the relative money value of Gas and Coal as calorific agents, we must take a comprehensive view of all the contingencies inseparately attached to each.

The use of coal entails first the trouble of purchase, then it must be stored away, and when it is safely in the bin, the side-walk on which it was dumped presents such an unseemly appearance that it must needs be scrubbed. Then kindlings must be purchased and stored, and as they are wanted, perhaps for use on an upper floor, both coal and wood must be carried from the cellar. When each new fire is built, the ashes from the last one must be removed from the premises, involving, no matter how careful, the scattering of some over the room, to the destruction of carpets, furniture, etc.; then comes the time lost in waiting for the fire to burn. If only a little fire is needed to boil a pint of water, substantially the same operations must be gone through with, that would be necessary to make a fire to cook a dinner. After it is built it must be watched, or it may get too hot and burn the meat, or go out and leave the water unboiled.

With gas all this is changed – it entails no journeys up and down stairs, it makes no dirt, necessitates no labor; it does not smoke, nor burn too fast or too slow; it requires no care. The gas has only to be lighted and adjusted to give the flames required, the food placed in the oven and, with very little experience, the time required for cooking it may be so correctly determined, that no further attention need be paid to either the fire or oven until done. The gas is instantly turned off, and thereby all the waste that occurs with a coal fire is saved.

The Oven connected with these Stoves is of much larger capacity than those usually furnished with Gas Stoves, and by the peculiar arrangement of its interior, a greater amount of heat is utilized than by methods heretofore employed. These Stoves and Ovens are for sale by the inventor, John R. Shirley, at his Show Room and Manufactory, corner of Pine and Eddy Sts., Providence, R.I., where also may be seen a good assortment of Crystal, Bronze and Gilt Gas Fixtures of his own make, and at reasonable prices.

Prices of Stoves – Single Stove, $1.75; Double Stove, $4.50; Oven, can be used on either Stove, $4.50. Liberal discount to the Trade. These Stoves sent to any address, free of package, upon receipt of price.



Optional Questions for *Starting a Coal Stove*

Reading Carefully

1. List the different kinds of supplies (other than coal) that the writer suggests a household would need to keep its coal stove running properly.

2. Name three problems with wood that the author says might lead to the coal not catching fire.

3. What careless act in using the stove could set fire to the home?

Thinking It Over

1. Imagine that you are going to cook breakfast, which you will serve to your family at 7 am. What time do you think you would have to get up to start the stove?

2. Who in the household do you think did this work? Do you think it was hard work? How do you know?

3. Can you think of any other household tasks that took a lot of labor in 1900 and now are much easier? What energy sources are used to do the tasks now? How has this changed the need for physical labor in the household?

4. Do you think running a household today takes more thinking than it did in 1900? Why or why not?

Finding Out More Information

1. Find an advertisement for a modern coal stove. Do they provide directions on how to start a fire in it? How do their directions compare to these?

Optional Questions for *Using a Gas Stove*

Reading Carefully

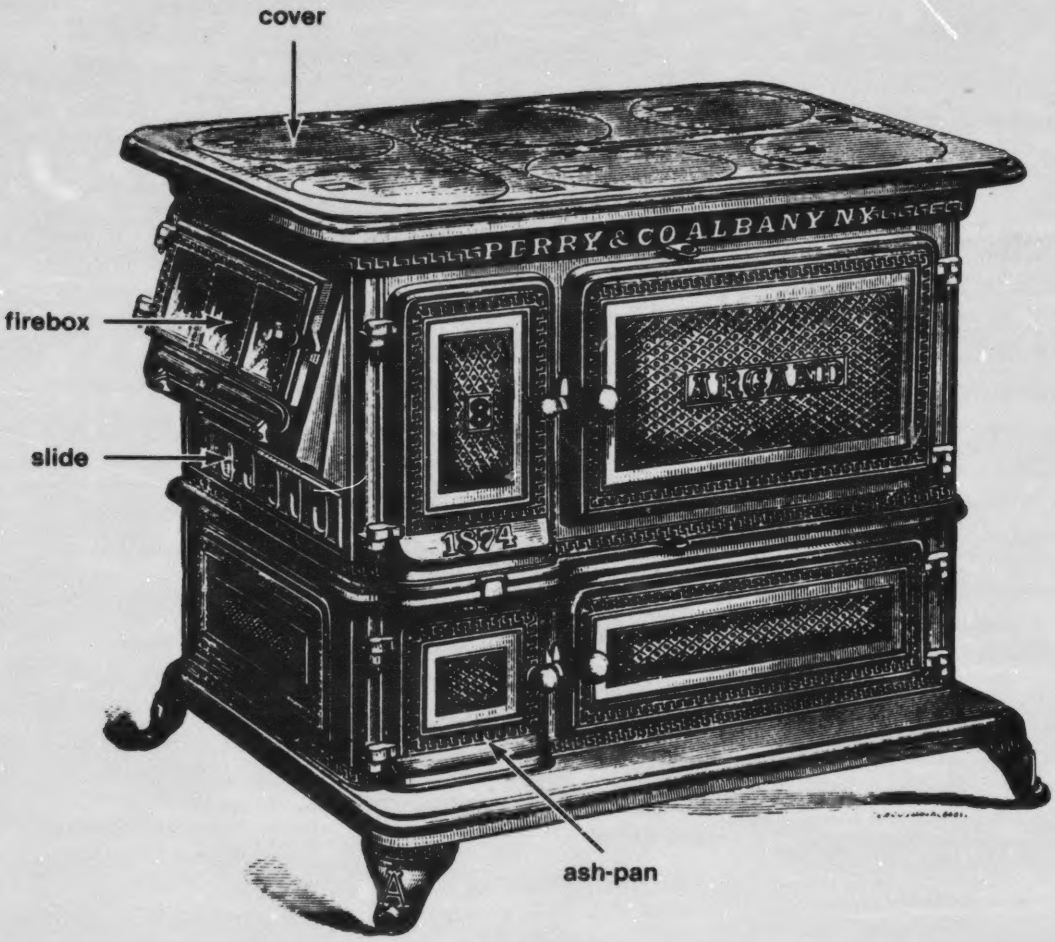
1. How big a piece of meat could be roasted in Shirley's oven?
2. In what city and state was Shirley's business?

Thinking It Over

1. What does the author mean by "the contingencies inseparately attached to each."
2. The writer says that cooking with gas is especially advantageous in the summer. Why do you think he thinks so?
3. What features of the stove does the writer emphasize?
4. This reading is an advertisement. The author was trying to sell stoves. From what he chooses to emphasize, what do you think the writer thought was the biggest problem in getting people to buy gas stoves?
5. Judging by this advertisement, do you think people at that time thought gas was cheap or that is was expensive?
6. How do you think the purchase price of gas stoves compared with that of coal stoves? What major expense *would* a household installing a gas stove incur?

Finding Out More Information

1. Find a modern ad for a gas stove in a magazine. Write a brief summary of the ways the two ads differ.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PERRY & CO ALBANY NY
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A

Gasoline

Hiram Percy Maxim was an American inventor, the son of the inventor of the Maxim machine gun. Hiram graduated from MIT in 1886 at the age of 16, the youngest of his class, and went to work for electric equipment companies. At 20, he became superintendent of a manufacturing plant. In his spare time, he became interested in trying to build an automobile, which is the subject of this reading. He succeeded after a fashion, and as a result was hired by the largest bicycle manufacturer of the day—designing automobiles for them.

Probably Maxim's most famous invention was the silencer for rifles. He got the idea for it while trying to design a muffler for cars.

Towards the end of his life, Hiram wrote two books: the one from which this reading is taken, and another, *A Genius in the Family*, an hilarious account of the young Hiram's adventures with his eccentric father. If you enjoy this reading, you might look for the other book in your library.

Once I had decided upon the type of engine I was to use, I could now crowd on all pressure and concentrate on one specific problem—the design of the engine. I knew engines pretty well, but I did not know very much about gasoline. That it was bought in paint shops, that it was about as temperamental as dynamite, was very volatile, would remove grease spots from clothing, and was a petroleum derivative was about the total of my knowledge. I decided to get a sample and familiarize myself with it. I would find out how best to vaporize it and ignite it, and I would acquire some notion as to how much real kick it would develop when exploded.

I visited a paint shop in West Lynn and asked that an eight-ounce bottle be filled. The proprietor looked me over as though purchasing gasoline were a highly suspicious proceeding. He supplied my wants, but I was to hear from him later about this gasoline business. After six o'clock, when the factory had closed, I brought out my little bottle of gasoline and took a fond look at it. It was a colorless, limpid, innocent-appearing liquid. No one would ever suspect it to be loaded with epoch-making possibilities. Gazing at the bottle and its fascinating contents, I saw in my mind's eye thousands of drops. Each one of these little drops, vaporized and mixed with air, could develop ten times the thrust against my bicycle pedals that I could develop with my legs. The contents of that bottle could develop enough power to take me to Salem, if only I could provide a cylinder in which to explode it and a piston with the connecting-rod and crank to translate the explosions into mechanical motion.

* * *

My first experiment was a rough "get acquainted" test. My idea of such a test was to introduce a drop out of the bottle into an empty six-pounder cartridge-case and then touch it off with an ordinary match....It was hardly a precise experiment; but it would tell me what I wanted to know.

I began with one drop. I was excited, for I felt this might be an historic moment for me. Standing back, I scratched the match and tossed it in. There was a very short and a very ominous pause. Then the end of the world came, it seemed to me. There was a terrifying explosion, fire shot up out of the cartridge-case, the latter staggered drunkenly on the bench, and the match I had thrown in went hurtling to the

From *Horseless Carriage Days*, by Hiram Percy Maxim. (Third edition. New York: Harper & Brothers, 1936.) pp6-15. Copyright ©1936, 1937 by Harper & Brothers. All rights reserved. Reprinted by permission of the publisher.

ceiling. It was evident that there was about a thousand times more kick in a drop of gasoline than I had pictured in my wildest flights of imagination. No wonder the old chap who filled my bottle was suspicious. I did not know it at the time, but I had exploded the first of countless millions of gasoline charges that I was destined to explode in succeeding years.

• • •

It must be borne in mind that at this time, 1892, there were no spark plugs in the world, no carburetors, no magnetos, no good dry cells, and precious little practical knowledge about explosion engines, not to speak of clutches, change gears, differentials, steering gears, and tires. I even had no definite idea as to where on a vehicle the engine should be placed. Every detail about the automobile which we have today had to be learned in the hard school of experience. I even was not decided as to the principle on which the engine should operate. Whether to use the four-cycle principle of Otto which gave only one power stroke out of four strokes of the piston, or the two-cycle principle of Clerk and others, which gave one power stroke out of two strokes of the piston, was very difficult to decide.... After a terrible tussle with myself I settled upon the four-cycle principle of Otto. I wince as I record that I settled the size of my cylinders and the stroke and number of cylinders before I had the least notion of what the engine would have to drive. I can only excuse this on the score of youth.

• • •

(After months of night work, Maxim finished a design for an engine.) I passed up the carbureting arrangement, muffler, manifolds, and lubricating systems, as minor details, the designing of which could be tossed off at any convenient time! Another horrible example of how *not* to proceed. *(It required several more months to actually build the engine. Finally it was finished and ready for testing.)* I thought it the most ravishingly beautiful bit of machinery the hand of man had ever created.

As might be expected, I had trouble starting my new engine. The whole future looks black and forbidding after spending a week unsuccessfully cranking a cold gasoline engine. I used up a prodigious quantity of gasoline. Most of it dripped on the floor and was wasted. In fact, *all* of it was wasted, for a long time. The engine certainly did not consume any in running. I was compelled to return to the paint shop frequently to have the eight-ounce bottle refilled. Some days I went twice.

After a fortnight of this sort of thing the old gentleman who ran the paint shop became suspicious. From the beginning he had acted as though he supplied my gasoline demands under protest. When things reached the pass where I was in every day for eight ounces of gasoline, and sometimes twice in the same day, he became alarmed. Intently regarding me over the tops of his glasses one day, and holding my empty eight-ounce bottle in a threatening way, he asked, "What are you doing with all this gasoline?"

It is interesting to note that I was ashamed to tell him that I was developing a gasoline-engine for a road vehicle. I feared he might have me arrested.…The old chap realized it was not my desire to convey any further information, and as it was his business to purvey gasoline, among other commodities, he saw he must fill my eight-ounce bottle as often as I was willing and able to pay for it. But he disapproved of any young man consuming such quantities as I consumed. So, by way of relieving himself of what he probably considered his moral responsibilities, he announced: "Well now, young feller, let me tell you somethin' you probably don't know. Everybody who ever experimented with gasoline got killed doin' it. Not a one of 'em alive today. I'm just a warnin' of yer—that's all."

* * *

In the forty-odd years that have passed since the colloquy in the paint shop, I have many times reflected upon what that old fellow typified. Had I taken him into my confidence, back there in 1893, and explained to him that conditions were ripe for a gasoline-engine-propelled road vehicle, that I was likely to be among the first to have one running, and that I believed it would become a big industry, he would have branded me as a person whose sanity was askew. He would have been backed up by every solid business man. And yet it so happened that I was right and all the solid business men would have been wrong. Since that day I have been identified with several other new industries; and I have found that the solid business man of recent years is an entirely different sort of being from his prototype of forty years ago. Today, anything is believed possible. So much money has been made from startlingly new things that the most revolutionary idea is given serious consideration. That old codger in the paint shop forty-odd years ago went to his grave never dreaming that a great new industry had touched him when I took my eight-ounce bottle in and asked to have it filled with gasoline.

Reading Carefully

1. In what year did the events described take place? In about what year is the author writing?

2. What source of power did Maxim imagine his gasoline-engine replacing?

3. Where did Maxim go to buy gasoline?

4. What was one use of gasoline before it became a fuel for engines?

Thinking It Over

1. Was the "old codger" right in thinking that gasoline was a dangerous substance? How do you know?

2. When Maxim thought that gasoline had "epoch-making possibilities," what do you think he was imagining? Was he right?

3. Maxim says he was destined to explode "countless millions of gasoline charges." What does he mean? How is this possible? Has anyone in your family exploded "millions of gasoline charges"? How many charges per minute?

Finding Out More Information

1. Many people carry spare cans of gasoline in the trunks of their cars, or keep one in their garages. Give a report to the class on whether this should be done-and, if so, how. One place to ask for information in your local fire department.

Portable Power

Objectives

This lesson contributes to students' understanding of the following concepts:

Like the reciprocating steam engine, the internal combustion engine employs a piston in a cylinder.

Development of the internal combustion engine provided a lightweight, portable source of mechanical energy.

Petroleum was identified at an early date as a source of fuel appropriate for internal combustion engines.

Format of the Lesson

Review of characteristics of steam engine

Comparison of steam engine and internal combustion engine.

Rise of internal combustion engine

Materials Needed

overheads **Piston in Cylinder, Steam Engine Overlay, Internal Combustion Overlay.** Make these from masters at the end of the lesson. It is helpful if the combustion areas on the overheads are colored red to emphasize the change from external to internal combustion.

activity sheet **Portable Steam Engines**

overhead **Change in Waight of a One-Horsepower Engine.**

worksheet **Small Engines Today.**

Reviewing the Steam Engine

Using the overhead transparency, review the operation of the steam engine. Steam from a boiler enters the cylinder, the pressure moves the piston and, as the piston moves, the steam expands and is thereby cooled; the steam is exhausted to a condenser or into the atmosphere.

Remind the class what a boon the steam engine was to humankind. It provided great quantities of power on demand. Unlike the windmill, the steam engine could be operated whenever power was needed, not just when the wind was blowing. Unlike the waterwheel, the steam engine could be put anywhere, not just on rivers. But could it really be put anywhere? How portable was the steam engine?

Pass out the worksheet, **Portable Steam Engines.** Explain that this a real advertisement of an American manufacturer in the year 1860. Ask students to complete the questions at the bottom of the sheet.

The Difficulties of Making a Portable Steam Engine

Discuss the questions. Summarize that, in small sizes, the steam engine was expensive and heavy.

One way of increasing the efficiency of a steam engine is to raise the pressure. But to increase the pressure, the boiler must be strengthened, which makes it heavier.

Efficiency can also be increased by using a condenser. But a condenser weighs something, and it needs a supply of coolant, which can be hard to get in portable applications. In steam locomotives, for example, there was no condenser. The thermal efficiency of the engine was sacrificed to decrease the weight the engine would have to pull.

Size and weight were only some of the difficulties. Handling the fuel was messy and cumbersome. It took a while to get up pressure. Some of these problems have been overcome in modern small steam engines, but back in the 1800s some of the people who were using steam engines in tractors, cars, and other machinery began to look for another, better way of getting portable power.

Internal Combustion Engine

(Replace steam overlay with the internal combustion overlay.)

The only purpose of the fuel in the steam engine is to heat water and make a hot gas: steam. There is another way to make a hot gas. Instead of burning the fuel under a boiler, we could burn it inside the cylinder itself. The burning fuel would heat the air in the cylinder, and the pressure would push down the piston. Then the air would be expelled, and a new supply of air and fuel brought in and ignited. Because the burning takes place inside the engine instead of outside, this kind of engine is called an **internal combustion** engine.

People had the idea for an engine like this as early as 1794, but they couldn't build a practical one.

What Fuel Is Suitable For Internal Combustion?

Now the question becomes, what kind of fuel is best for an engine like this?

Fuels can be solid, liquid, or gas. Which do you think would work best in an internal combustion engine? (ANS: Liquid or gas. How could we get the solid into the cylinder?)

That is what the inventors of the internal combustion engine thought, too. Also, they couldn't use any fuel that left behind a lot of ash. The first engines used gases. By 1860, a successful engine that ran on gas (illuminating gas, not gasoline) was being sold.

However, storing and transporting a gas is a problem. So engineers began to try liquid fuels, like alcohol, kerosene, and gasoline. A liquid fuel would have to vaporize easily, and it would have to be available in great quantities. Remember that, up until this time, gasoline was an unwanted by-product in the manufacture of kerosene for lamps. Gasoline turned out to be the best compromise fuel.

The Evolution of the Internal Combustion Engine

Put on the overhead transparency of the evolution of the internal combustion engine. Point out the progress in size and weight.

Homework Assignment

Ask students to fill out the worksheet on internal combustion engines.

Additional Activities

Field Trip

Arrange a field trip to an auto repair shop or to your high school auto repair class. Prepare for the visit by having students learn the functions of a few fundamental parts of most internal combustion engines: carburetor, sparkplug, cylinder, piston, valve.

Model Engines

Most schools have students whose hobby is building miniature, power-driven airplanes, boats, or cars. Invite one of these students to your class to demonstrate the operation of a model engine. In many models, the movement of the piston can be seen through an open port on the side of the cylinder.

Visible V-8

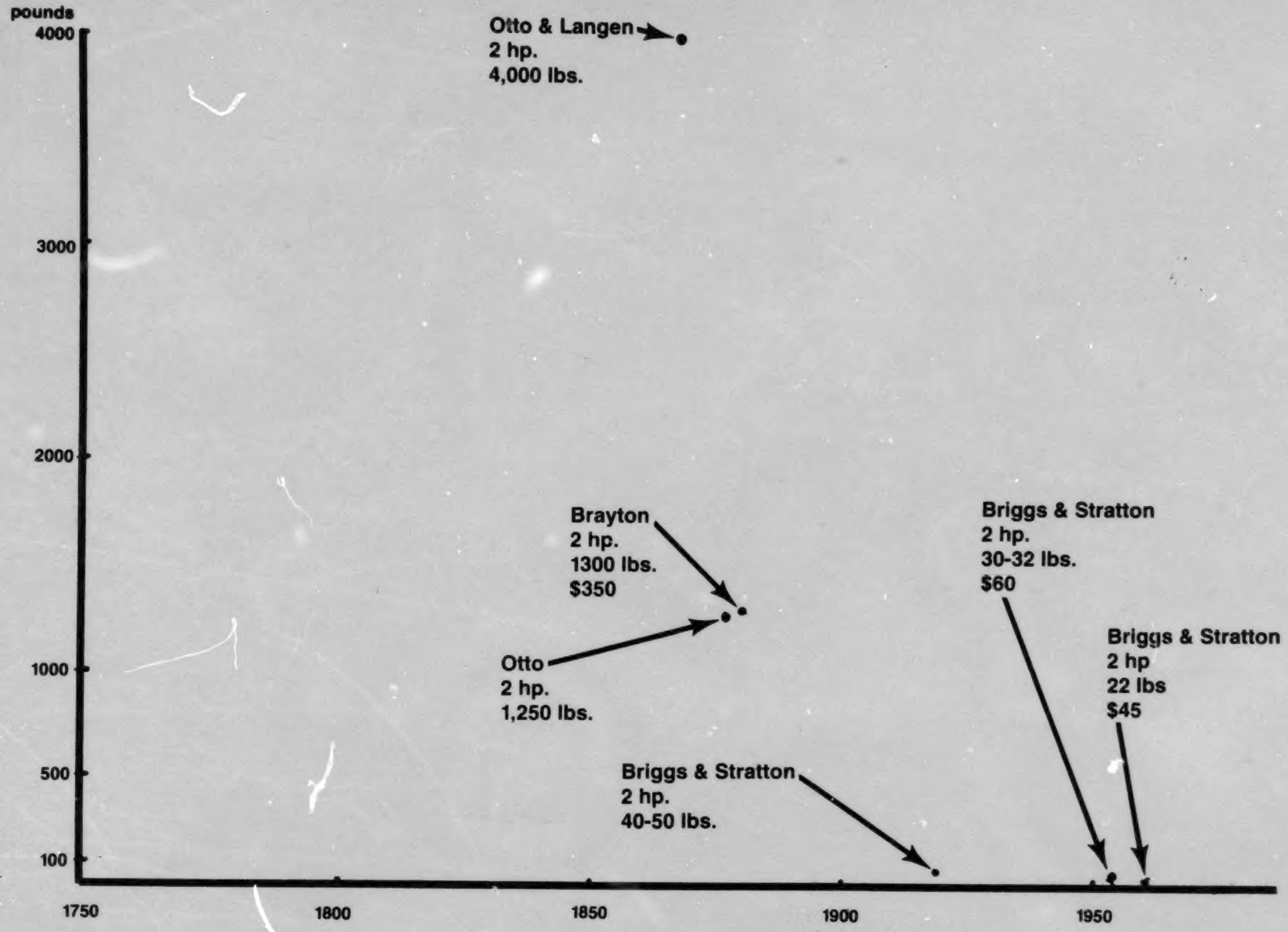
A kit is available (manufactured by Revell, $26.50) for building a clear plastic, working model of a V-8 auto engine. If any student in the school has built one of these, invite him or her to bring it in and show it to your class.

Projects for Independent Investigation

1. Investigate the difference between fuel injection and carburetion in an automobile engine. Make an oral report to the class.

2. Report to the class on the difference between a gasoline engine and a diesel engine.

3. Investigate the history of steam-powered automobiles. How well did they perform? What were their advantages and disadvantages? Give a brief talk to the class. As part of your talk, explain why you think the steam engine lost out to the gasoline engine in motor vehicles.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Briggs & Stratton
2 hp
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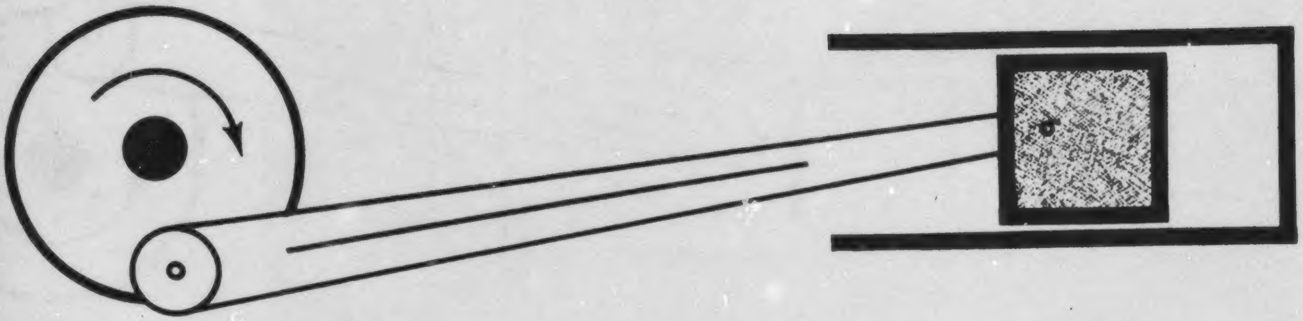
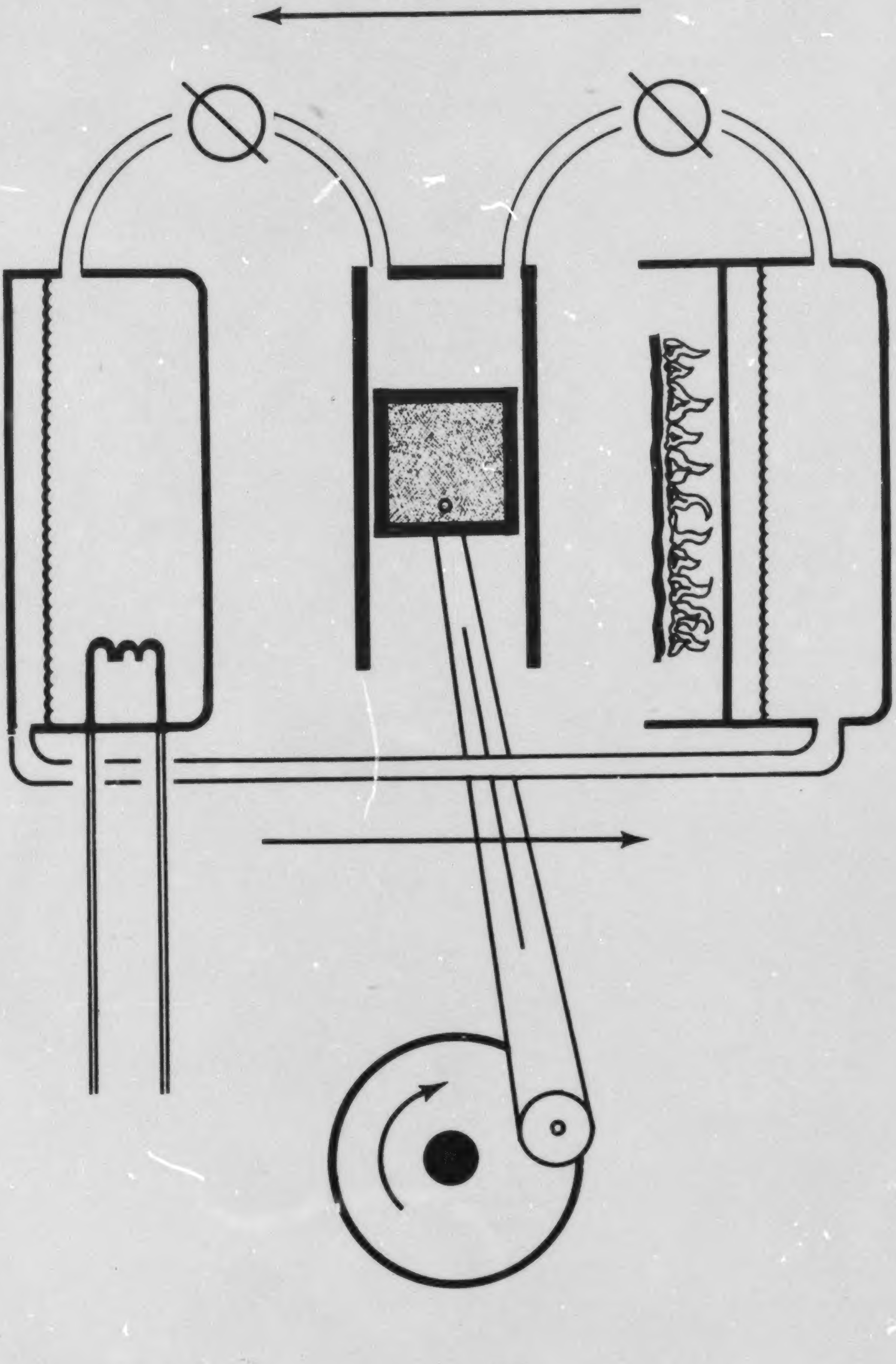
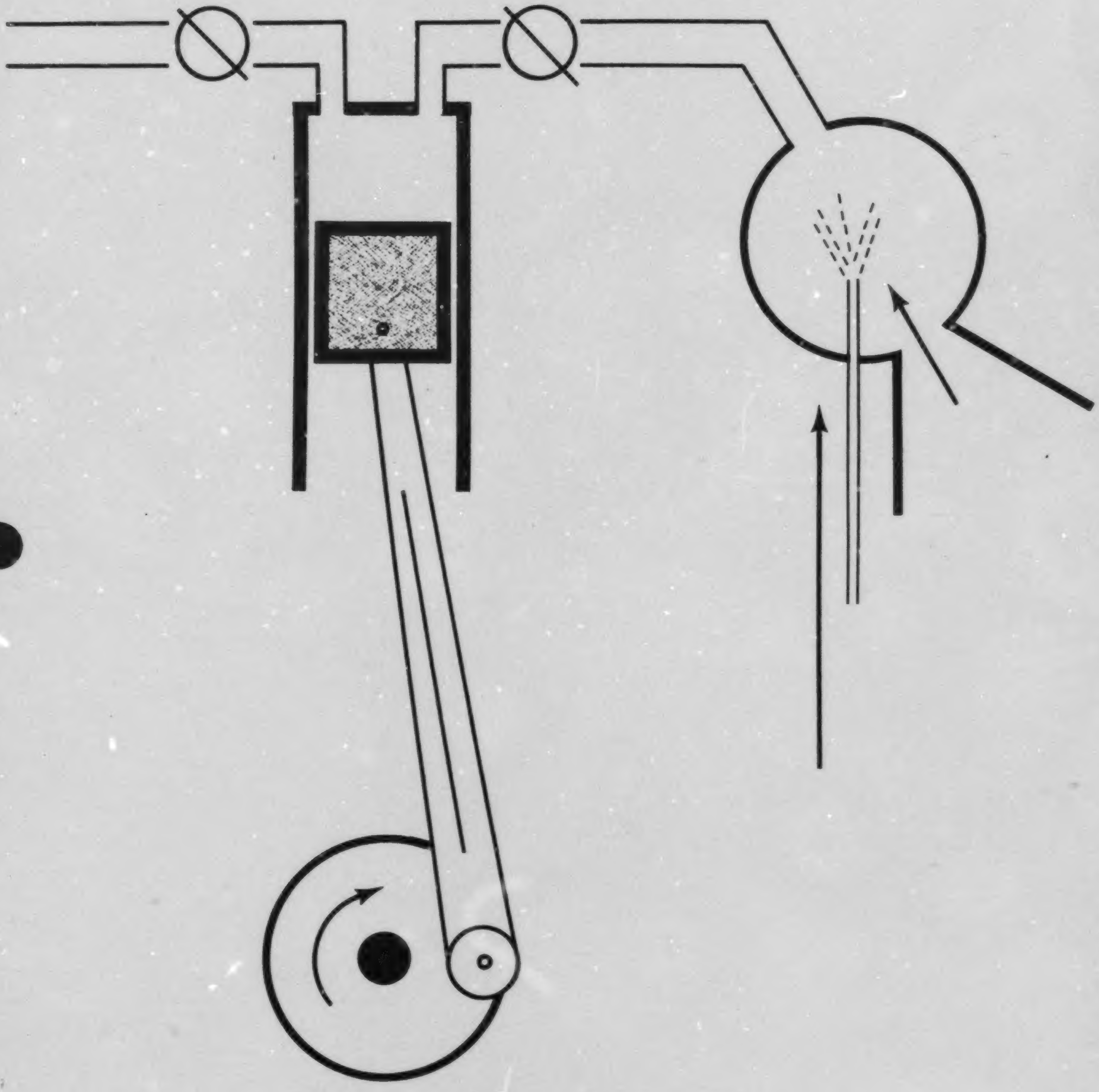
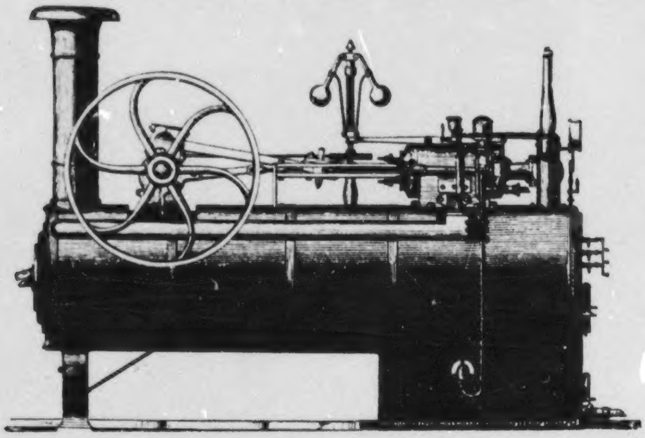






PORTABLE STEAM ENGINES.



No.	Power.	Boiler.	Cylinder.		Speed. Rev. per M:n.	Weight.	Price.
		Fire Surface.	Diam.	St'ke.			
	H. P.	Sq. Ft.	In.	In.		Pounds.	Cash.
1	2	22	3	9	175	2,200	$300 00
2	2	40	3	9	175	2,350	365 00
3	2½	47	3½	9	175	2,500	385 00
4	3	44	4	10	150	2,700	425 00
5	4	50	4½	10	150	2,900	450 00
6	5	60	5	10	150	3,200	475 00
7	6	90	5½	10	175	3,700	575 00
8	7	97	6	10	175	3,900	600 00
9	8	100	7	10	175	4,500	675 00
10	12	139	8	12	175	5,800	840 00
11	15	161	9	12	175	6,500	950 00
12	20	286	10	18	125	10,300	1,300 00
13	25	308	11	18	125	11,500	1,400 00
14	30	357	12	18	125	13,000	1,550 00
15	35	432	14	18	125	15,000	2,000 00
16	40	510	16	18	125	17,000	2,300 00

THESE Engines are very compact and complete, having a feed-water Heater, Force-Pump, Regulator, Belt-Pulley, turned on the face, Steam-Gauge; in short, every thing necessary to set them in operation, on the introduction of water and fuel, (either wood or coal,) to the boiler, and applying a belt. No smoke-pipe is furnished with them, as it is bulky, liable to injury if sent unboxed, and expensive to box up. Eight, ten or twelve inch stove-pipe, of heavy English sheet iron, is all that is required, and that is to be had anywhere, in any length the location demands.

The Boilers are of best American iron, strong, well made, and supplied with fusible safety-plug; and warranted to bear a cold-water test pressure of 200 lbs. per square inch, and a constant working pressure of 120 lbs. They embrace the principles of the best modern locomotives, are well made, without finish for show, and are capable of working much above the power inserted in table. Extra finish at extra prices. Our No. 10, Extra Finish, can be seen at the Varnish and Paint Store of STIMSON, VALENTINE & Co., No. 36 India Street, Boston.

The medium sizes, such as Nos. 5, 6, 8, 9, 10, 11 and 12 are always in progress, and can generally be finished to order in from three to six weeks.

☞ All Engines fired up and tried before they leave the shop, and warranted tight, safe, and in all respects ready for operation. Failing to give satisfaction, they will be taken back, and the money refunded.

A good strong running gear, arranged so as to be easily attached and detached at pleasure, will be supplied at from $125 to $225 extra—forming a useful wagon when separate.

ADDRESS, **J. C. HOADLEY, Lawrence, Mass.**

This advertisement by an American manufacturer of steam engines actually appeared in 1860. One dollar in 1860 could buy about as much as $8.70 could in 1979. Two horsepower is about the size of a big lawnmower engine. A Volkswagen "Beetle" engine puts out about 40 horsepower. Read the advertisement, and then answer the questions.

1. Would Model 16 fit in a Volkswagen Beetle? Why? Do you think a Beetle engine would be worth $20,000?

2. Would Model 1 fit on a lawnmower? Why? Do you think a lawnmower engine is worth $2,610?

3. Model 1 costs $300 and puts out 2 HP. That is $150 per horsepower. If you paid the same amount for each horsepower for Model 16 as you did for Model 1, how much would Model 16 cost?

4. Model 16 has twenty times the power of Model 1 (40 horsepower versus 2 horsepower). How many times the price is it? How many times the weight?

5. As the engine size decreases, why does the price decrease more slowly than the horsepower? Why does the weight decrease more slowly than the horsepower?

Using Portable Power

Lightweight, low-cost internal combustion engines are in use all around us. Automobiles are an obvious example. Some other uses aren't so obvious. Here is a list of some activities. For each activity, try to name as many machines as you can that are used in that activity and that incorporate an internal combustion engine.

Sport fishing:

Farming:

Firefighting:

Gardening:

Model building:

Warfare:

Notes

Are We Really Running Out of Oil?

To know when we'll "run out" of oil, we need to estimate two things: how fast we use it, and how much we'll be able to get from the earth. (Of course, how much we get also depends on how much we are willing to spend getting it.)

The following selection is taken from the conclusion of *Giant Oil Fields and World Oil Resources*, a study by Richard Nehring for the Central Intelligence Agency. (Report R-2284-CIA, Santa Monica, CA: the Rand Corporation, 1978). This public document provides one of the most authoritative estimates available of how much oil there really is.

The footnotes called out by letters are Mr. Nehring's; those called out by numbers are additional explanations that we have added.

Ultimate World Oil Resources

The ultimate recoverable conventional crude oil resources of the world are estimated to be 1700 to 2300 billion barrels.[a] This includes 335 billion barrels that had already been produced by the end of 1975, 676 billion barrels of proved and probable reserves, from 263 to 555 billion barrels to be added from future discoveries, and from 420 to 730 billion barrels to be added from further development of and additional recovery from known fields. Additional recovery is thus projected to provide 57% to 61% of future additions.

The range of 1700 to 2300 billion barrels incorporates most of the major uncertainties in world oil resource estimation, assuming that the exploration of unexplored provinces will yield results basically analogous to those in the explored provinces[1] and that future development and recovery worldwide will be basically comparable to that likely to be achieved in the most highly developed fields today. If the ultimate amount proves to be outside this range, one or more non-analogous events or developments will have to occur.

Ultimate conventional crude oil resources will be less that 1700 billion barrels only if there is a sharp drop-off in discoveries of giant and large fields (most likely from a lack of new major provinces), and if additional recovery efforts yield poor results, even at significantly higher prices. For ultimate conventional crude oil resources to be more than 2300 billion barrels, one of the following developments will have to occur:

(1) proportionately more of the unexplored provinces prove to be major provinces than have the explored provinces;

(2) a few new major provinces, larger than any known province other than the Arabian-Iranian Basin (i.e., 50 to 100 billion barrels and several super-giants each), will be opened up;

(3) one or more Ghawar-size fields will be discovered; or

(4) additional recovery efforts, particularly in the Middle East, prove to be highly successful.

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[a] Although the components do not quite equal the totals, the estimate is rounded off because the uncertainty in estimation does not permit any meaningful numbers beyond two significant digits. Readers familiar with recent estimates of world oil resources will notice that the midpoint of the range coincides with the "consensus" estimate of 2000 billion barrels. Contrary to appearances, the agreement is purely fortuitous, for the totals presented here were not determined until the disaggregated analysis was completed.

[1] "Province" is the word geologists use to describe a geographic area sharing the same geological structure. The author is assuming that no "freakish" geology will be found in areas not yet explored. A "non-analogous event" means a discovery unlike anything found so far.

None of these developments are impossible. It appears to be most unlikely, however, that ultimate conventional oil resources would be less than 1700 billion barrels. The known prospects in the current producing provinces and the record of continued giant field discoveries since 1975 suggest that a very sharp drop-off in discoveries is improbable. The prospects for secondary recovery alone, a technique that has been used worldwide in many geologic circumstances, are substantial, particularly in the Middle East.

Reducing the uncertainty at the high end of the estimate cannot be so easily substantiated. Each of the three logical possibilities for future major discoveries would be a non-analogous event, given the past history of exploration. They are excluded from the range estimated here because they are non-analogous and because a sketchy survey of the known geology of the unexplored and lightly explored provinces did not indicate a highly promising potential. However, because exploratory surprises do occur, the most recent being the opening up of the Reforma area in Mexico, each of these possiblilities should be kept in mind as exploration continues. Further exploratory activity, particularly in the next 10 to 20 years, will provide the information to indicate whether any of them are realistic. Very successful recovery efforts resulting from high rates of investment and improvements in recovery technology appear to have a reasonable probability of occurring. They are excluded from the range estimated here because they fall outside the realm of present experience. If they do occur, their primary effect will be on oil availability in the next century.

The distribution by field size[2] of ultimate crude oil resources is expected to change only slightly from the present distribution. (An approximate ultimate distribution is provided in Table 5.1[b].) Super-giant fields will become somewhat less important: large non-giant fields will become somewhat more important. Other giant, large non-giant, and other non-giant fields are predicted to comprise a greater proportion of future discoveries than they have in the past. The share of additional recovery from super-giant fields — known, potential, and prospective — is predicted to be greater than the current proportion of known recoverable resources in super-giant fields, primarily because of additional recovery from the super-giant fields of the Middle East.

Table 5.1
Estimated Distribution of Recoverable Oil Resources of the World by Field Size

Field Size	Number	Amount (In billions of barrels)
Super-giants	45-55	825-1065
Other giants	475-550	475-635
Large non-giants	1000-1400	200-350
Other non-giants	No estimate	200-250
Total		1700-2300

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[2] The author classifies fields by size into the following groups: super-giant fields, at least 5 billion barrels of known recoverable oil; giant oil fields, at least 500 million barrels of known recoverable oil; larger non-giants, 500-100 million barrels; other, everything less than 100 million barrels.

[b] The number of fields in each category reflects both new discoveries and transfers from other categories because of reserve growth.

The geographic distribution by region (including the adjacent continental margins) of ultimate conventional world crude oil resources is projected to change only slightly. (An approximate distribution by region is provided in Table 5.2) Despite the high promise of the Reforma area of Mexico, the importance of North America is projected to decline slightly. The overall proportions in South America, Eastern Europe/the Soviet Union, Africa, and the Middle East are expected to remain basically unchanged. The respective shares in Western Europe and Asia/Oceania (including Antarctica) are expected to increase slightly. Considering that these disaggregated projections are somewhat more uncertain than the range of the total, these differences are basically insignificant.

The geographic distribution projected here differs significantly from those of most other estimates with similar totals. In particular, other estimates[c] project considerably more for the Soviet Union (twice as much in some cases), somewhat more for Western Europe and Asia/Oceania, and much less for the Middle East. The estimates for North America, South America, and Africa in Table 5.2 and in other estimates are roughly similar, given the prevailing uncertainty. The primary reasons for these differences are (1) other estimates have not explicitly incorporated an assessment of the additional recovery potential of the Middle East, and (2) other estimates overstate the oil potential of the relatively unexplored provinces in the Soviet Union, not taking into account the fact that those that are beginning to be explored are turning out to be principally gas provinces.

Table 5.2
Estimated Ultimate Conventional World Crude Oil Resources by Region
(In billions of barrels)

Region	Known	Potential	Total
North America	179.8	100-200	280-380
South America	68.4	52-92	120-160
Western Europe	24.6	24-45	50-70
Eastern Europe/ Soviet Union	102.4	63-123	165-225
Africa	75.6	45-94	120-170
Middle East	509.9	350-630	860-1140
Asia/Oceania	50.8	54-104	105-155
Total	1011.5	688-1288	1700-2300

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c. For example, Moody and Esser, "An Estimate of the World's Recoverable Crude Oil Resource" and the consensus estimate published by the Conservation Commission World Energy Conference, Report on Oil Resources.

Oil Resources and Oil Availability

The preceding review of world oil resources suggests that there will ultimately be 1700 to 2300 billion barrels of oil recovered from conventional crude oil fields. This range, less cumulative production, is equivalent to 60 or 90 years of world consumption at current rates. However, it does not include the hundreds of billions of barrels that could become available from heavy oil (tar) sand and oil shale deposits.

Several factors will determine the rate at which the ultimate resource will become and be available. Because the ultimate resource is concentrated in giant and super-giant fields, the factors determining world oil availability essentially revolve around giant fields: the rate at which they can and will be discovered, the rate at which they will be developed and produced, and their characteristics and economics.

For many of the Arctic and oceanic provinces, the necessary exploration or production technology is not yet available and is unlikely to be so for at least another decade. The technology necessary for exploration and production offshore in Arctic regions (except for shallow waters) is currently in the conceptual and developmental stages in the United State and Canada. Its application in the Soviet Union is in the even more distant future. Although exploratory drilling is now possible in waters 300 to 1500 meters deep, the technology for production in waters of this depth is still in the conceptual and developmental stages. Thus, even if giant fields are discovered in some of the most promising remaining unexplored provinces, production is not likely to be mechanically possible before 1990. In other areas, such as the off-shore areas of China, the necessary technology for exploration and production exists, but may not be employed rapidly for a number of political reasons (although there are recent indications that Chinese oil policy may be moving toward a more rapid development). The implication of the unavailability and the lack of full utilization of the necessary technology is that world oil availability between now and at least 1990 will be determined almost entirely by the availability of oil from known and yet-to-be discovered fields in known producing provinces.

Because production between now and 1990 will come almost entirely from the known producing provinces, near- and medium-term oil availability will depend primarily on the production policies of the OPEC countries. The current world potential for higher production is concentrated in these countries, particularly Abu Dhabi, Iraq, Kuwait, and Saudi Arabia. The extent to which it will be developed and used depends, first, on whether these countries will undertake or permit the necessary investment in additional productive capacity, the cost of which in many cases will be an order of magnitude[3] or more higher than most of the capacity developed in these countries to date (but one that still provides a complete payback on investment at present world oil prices within one to two years at most).

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[3] "An order of magnitude" — different by a factor of ten; the difference between tens and hundreds, or between thousands and tens of thousands.

A key factor is the point at which investments in secondary and enhanced recovery operations in giant fields will become desirable in the major exporting countries. Second, the development of additional capacity depends on the extent to which these countries, particularly Saudi Arabia and Abu Dhabi, will want to determine the world crude oil prices. The availability of excess capacity, which they essentially control, will be the principal factor in determining the rate of increase in world oil prices. It will not, however, be the only factor in determining world oil prices. The potential that could be discovered and developed outside the OPEC countries is sufficient to constrain prices for the next 10 to 15 years, assuming that demand does not grow by more than 1.0% to 1.5% annually. Finally, additional capacity will depend on their decisions as to the rate of depletion that they consider to be desirable for their long-run economic future. Oil production in all of these countries is concentrated in a handful of giant and super-giant fields. If no major fields or even if only a few more major fields are discovered in each, these countries will know that the rapid depletion of their existing fields means the depletion of their principal natural economic asset. Their decisions to increase production capacity are thus inescapably decisions about their long-run pattern of economic development.

Future oil availability will also be determined by the economic returns available to both producers and refiners. The period in which incremental oil production capacity could be added very cheaply, a period that was synonymous with the discovery and initial development of the super-giants, is past. Future increments to capacity will come from fields discovered in expensive environments, from fields with lower well productivity, from smaller fields, or from the application of secondary and enhanced recovery. In those countries where the investment in incremental capacity is made by the oil companies rather than by the government, the returns to companies will have to be sufficient if the necessary investments are to be made. Uncertainty, especially about future taxes and royalties, could be a major deterrent to further investment. Moreover, additional investments will be required in the refinery sector. A considerable amount of the undeveloped known potential productive capacity of the world is in heavy, high-sulfer oil fields. Altering existing refinery capacity to process a growing proportion of crude oils of this type will require major investments (although the investment per barrel of capacity is generally substantially less than the investment per daily barrel of enhanced oil recovery capacity). The refinery investment problem is magnified by the trends in the major oil-consuming countries toward implementing stricter sulfur emission standards and toward deemphasizing the use of oil in industrial boilers and for electrical generation. Producing a higher proportion of lighter, lower sulfur products from increasingly heavier, higher sulfur crude oils will require major changes in existing world capacity.

Notes

Depletion of Finite Resources

We were introduced to this activity in a workshop by Janis Philbin, formerly Program Assistant to the Energy, Food, and You Project, Washington State Office of Public Instruction.

Objectives

This lesson contributes to students' understanding of the following concepts:

As more of a resource is extracted, it becomes more difficult to extract what remains.

Technological innovation can change the availability of a resource.

Extraction of a resource often inflicts environmental damage; energy is needed for the process of re-creating a livable environment.

The resource that is most plentiful is not necessarily the easiest to get.

Format of the Lesson

(Before class, preparation of beads and cornmeal)

Divide class into teams

Scatter beads

Explain rules

Play several rounds

Discuss activity

Discuss meaning of results

Materials Needed

chalkboard

beads four colors, about two tablespoons each. These are the beads used by Boy Scouts in making Indian beadwork; they can be purchased at hobby stores for about 60¢ a color for a tube full. Reusable, though some will be lost each year. If you have no carpeting in your school, you can use short grain white rice dyed with undiluted food coloring and dried in the oven on a cookie sheet. The danger is that, if they become moist, they will leave batik patterns on anything they come in contact with.

cornmeal half a cup.

paper cups five.

OR

macaroni, rice, etc various shapes of macaroni (vermicelli, elbows, stars, spirals, shells, etc) or grains like rice and barley can be substituted for the beads. The larger items are especially appropriate if the activity is done out-of-doors in a grassy field. Since they are biodegradable, leftovers do not need to be picked up provided the field isn't used for contact sports. If desired, they can be dyed with food coloring.

dropcloth (optional) a plastic dropcloth such as painters can save a great deal of cleaning up. A 10' by 25' reusable dropcloth costs about $5.50. It beats sweeping.

Preparing the Beads

Before class, in a cup or other open container, make a mixture of differing quantities of four colors of beads plus one-half cup of cornmeal. The larger the class, the more beads you will need. An all-colors total of 200 beads per student is about right. For example, you could put in three tablespoons of blue beads, a tablespoon of red, five tablespoons of cornmeal, and so on. Set aside out of sight.

Setting Up the Activity

Ask the students to count off by fives, thus forming five teams scattered all over the room.

Appoint team leaders who are good at addition and give each leader a paper cup.

On the chalkboard, make a list of colors and assign each team a color (make one team cornmeal), and note the name of the leader. This will later form the left-hand side of the diagram shown below.

Take the cup of beads and fling the bead mixture out into the room, toward the ceiling (hang on to the cup)!

This act never fails to get the students' attention.

Explaining the Rules

Tell the class they are going to play a game, and these are the rules:

1. "When I say 'Go,' you have exactly one minute to pick up beads of your color — or grains of cornmeal. Stop immediately when I say 'Stop'."

2. "After I say 'Stop,' count how many beads you have picked up. Then give the beads to your team leader and tell her or him how many you had."

3. "Team leaders, add up your team's total score. Tell me what it is and I will enter it on the chalkboard. Leave the picked-up beads and cornmeal in this cup on my desk."

Playing

Say "Go!" Begin timing. Stop the scavenging after one minute.

When students have finished counting, enter the results on the chalkboard. Label the column "first minute" and rule a second column next to it. Label that column "second minute."

Tell the class we will do it again to see what changes.

Continue for as many rounds as are appropriate for the number of beads you tossed out, the difficulty of finding them, and the interest of the students. The final chart may look something like this.

	First Minute	Second Minute	Third Minute	Fourth Minute	Fifth Minute	?
1. red						
2. blue						
3. white						
4. green						
5. cornmeal						

Discussing the Activity: A Sequence of Questions

Predict how many beads we would get if we did another minute's search.

Which took more effort to find, the first bead you picked up or the last bead? Why? (ANS: Last.)

Do you think we would ever find all the beads? (ANS: Maybe not. The last ones will be very time-consuming to find.)

In most classes, more beads are collected in the second minute than in the first, since by then students have figured out where most of the beads went and have become more adept at picking them up. If this happened in your class, ask why the numbers in the second column are bigger than those in the first.

There was far more cornmeal than anything else. Why didn't we pick up more of it than anything else? (ANS: Too hard to pick up compared to beads.)

Can you think of anything we might do to get more cornmeal? (ANS: Get a vacuum cleaner.)

Discussing the Implications: Comparison with Extraction of Resources

In what ways are the beads like the earth's supply of petroleum, copper, or coal?

Would you expect it to require more effort to get the first million tons of coal or the "last" million? (ANS: Probably the "last" million, but it takes extra effort when you are just learning how to extract a resource.) Which costs more to get, the second million tons or the next-to-the-last million tons? (ANS: Clearly the next-to-last million tons.) Will we ever get all the coal or oil? Why not? (ANS: Because it would be so difficult to do, and hence so expensive, that it wouldn't be worth doing.)

Can new technologies change the relative importance of sources? How does the cornmeal resemble a very diffuse though plentiful energy source, like sunlight? How does it resemble tertiary recovery?

In what ways isn't this exercise really like extracting minerals? Was there a changing incentive to get the beads? Is there in extracting minerals? What is it? (ANS: Rising prices.)

Lastly, ask the students to look around the room. Has our "extracting minerals" wrought environmental havoc? Can we put it back to rights? Does it take energy to do so?

Have the students straighten out the room, thus demonstrating that reclamation does indeed require energy, and providing a natural ending for the lesson.

Notes

Unit Four
Energy from Nuclear Fission

Atomic? Nuclear?

It was an "atomic" bomb that fell on Hiroshima in 1945, and the government agency that took over the Manhattan Project was named the "Atomic" Energy Commission. Today, however, the "Nuclear" Regulatory Commission oversees reactor safety, and demonstrators call for no more "nukes." Is there any significance in this change in the choice of words? We suggest the change is a useful correction, and that to keep matters clear for your students you should use the term "nuclear energy" and avoid the term "atomic energy." Here's why:

Nuclear energy, whether from fission reactors, bombs, or the sun, involves the *nucleus* of the atom and only incidentally its electrons. When an atom of uranium splits, the energy released arises from the difference between the combined mass of the nuclei of the two new atoms and the mass of the old nucleus: Mass is lost; it has been converted to energy. The clouds of electrons orbiting the nuclei are involved in this reaction only in secondary ways. It is not, therefore, "atomic" energy.

On the other hand, we do get energy from a source that involves the atom as a whole, and we might appropriately call that "atomic energy" if we didn't already call it "chemical energy."

Let's consider the chemical reaction that provides most of the heat we get from fossil fuels: the burning of carbon. A carbon atom and two oxygen atoms from a molecule of oxygen (O_2) combine to make a molecule of carbon dioxide, CO_2. In the process heat is given off. Where did the heat come from?

If we measure the average distance between the electrons and the nuclei of the carbon atom and oxygen molecule we started with, and in the carbon dioxide molecule we end up with, we find that the average distance is less in the CO_2 molecule. This shrinkage is the source of the energy released when carbon is burnt.

Why should a change in distance between electrons and nuclei represent a change in energy? The answer lies in their differing electrical charges — negatively charged electrons and positively charged nuclei. There is a force of attraction between unlike electrical charges; this force holds the atom together. Think of another attractive force — gravity. The higher something is (that is, the greater the distance between its mass and the mass of the earth) the more energy you can get out of its falling. Thus engineers want as many feet of "head" in a hydroelectric project as possible.

Since the average electron-nucleus distances shorten when carbon burns, there is less energy stored in the atoms of a molecule of carbon dioxide than there was in the carbon and oxygen atoms we started with. The missing energy was released. How?

An atom is a bundle of constantly moving charges. As an electron drops closer to the nucleus, its interaction with other moving charges generates an electromagnetic wave — light.

The light — electromagnetic radiation — usually doesn't go far before it enters the vicinity of electrons in other atoms of the air or the carbon; when it does, it gives them a kick. When an electron gets kicked, the nucleus bound to it by electrical attraction gets pulled too, so the whole atom moves. It may transfer this energy of motion to other atoms by colliding with them. Thus, what began as radiation will largely become random motion on the molecular level or, in other words, heat.

It is through this process that chemical reactions give off energy. (Of course, there are also chemical reactions that take in energy — what does this suggest to you about the change in average electron-nucleus distances?) Since the energy-releasing process in a chemical reaction depends on the whole atom, both nucleus and electrons, we might call it "atomic energy." Of course, we don't.

Although there is no need to explain to students at this grade level the atomic nature of a chemical reaction, we hope you will agree it might be better to use the phrase "nuclear energy" to refer to reactions that only involve the nucleus.

Notes

Atoms and Elements

Objectives

This lesson is primarily a review of concepts most students will have mastered in previous years, including:

"Things" are ordinarily made of atoms, which are too small to see.

Atoms have a central core called the nucleus, surrounded by a cloud of electrons.

The nucleus is composed of protons and neutrons.

The electrons, protons, and neutrons in the atom are constantly in motion.

The electron has a negative electrical charge, the proton a positive charge, and the neutron has no charge.

Like charges attract; unlike repel.

The number of protons in the nucleus determines what chemical element the atom is.

Format of the Lesson

Discussion of the atom

Construction of nucleus diagrams

Vocabulary

atom
nucleus
nuclei
particle
electron
proton
neutron

Materials Needed

paper 2 sheets per student. Ideally, this should be heavy white unruled paper, suitable for preservation and bulletin board use. You will save these sheets for future years.

dots any two colors, about 2,300 of one color (for protons) and 3,200 of the other (for neutrons). The easy but expensive way to get the dots is to buy rolls of precut ¼" self-adhesive dots. However, each roll contains only 450 labels, so you would need about $10 worth of labels. This is expensive, although non-messy, easily managed, and productive of neat results. An alternative is to use a clear-drying glue, colored paper, and paper punches.

table of elements reproduced from this book.

felt tip pen black, three or four.

carbon samples such as charcoal, lampblack, or soot; graphite; diamond.

carbon compound samples such as carbon dioxide, sugar, calcium carbonate (chalk, limestone).

colored chalk two colors that roughly match colors of dots being used.

Reviewing the Atom

Ask for a volunteer to draw a diagram of an atom on the board.

Compliment student on pointing out the main parts of the atom: a central part called the nucleus, surrounded by a cloud of moving electrons.

Put the words "nucleus"and "electron" on the board.

Point out that the electron is called an atomic particle. What particles are found in the nucleus?

Write "proton" and "neutron" on the board.

Reviewing Electrical Charge

Point out that atomic particles can differ from each other in a number of ways. One way is in their electrical charge. Ask if anyone knows the charge on the electron, proton, and neutron.

As correct answers are given, mark next to the names of the particles on the chalkboard a "+" by the proton, a "−" by the electron, and a "0" by the neutron.

Put +'s and −'s on the drawing of the atom, to show the distribution of charge.

Point out that unlike charges attract (students will often have had experimental experience with this). What does this mean for the atom? It means electrical attraction helps keep the electrons and nucleus together.

Establish colors for the electron, proton, and neutron, using your colored chalks.

Elements

Explain to the class that chemists spent hundred of years trying to break substances down into simpler substances, the things they were "made of." One result of this search was that we found out there are substances that can't be broken down any further. We call these **elements**. In nature, there are 92 elements.

Show a charcoal briquet. Ask students to name the element that makes up most of the briquet. (ANS: carbon)

Show samples of charcoal, lampblack, and, if you can, diamond. These are different forms of carbon.

Even though these pieces look so different, if we could look at the atoms in these pieces of matter, we would see they are alike in a very important way: they all have 6 protons in their nuclei. That makes them carbon atoms.

Draw a carbon atom on the board, using the color code you've established. Give it 6 protons, 6 neutrons, and 6 electrons.

Show a sample of sugar. It is not an element, but instead is made of three ments. Which three? (ANS: carbon, hydrogen oxygen—it's a carbohydrate.)

All the atoms in the sugar that have 6 protons are carbon atoms. But some of the atoms don't have 6 protons. As a matter of fact, some have only 1—that makes them hydrogen atoms; and some have 8—that makes them oxygen atoms.

Other Nuclei, Other Elements

Draw a nucleus with 5 protons and 6 neutrons. Ask if this is carbon. No, it's the element boron, as in boric acid.

Draw a nucleus with 7 protons and 7 neutrons. Ask if this is carbon. No, it's the element nitrogen. 78% of the atoms in the room's air are nitrogen. So, a proto per nucleus makes the difference between the lampblack and the gas that makes up most of the air.

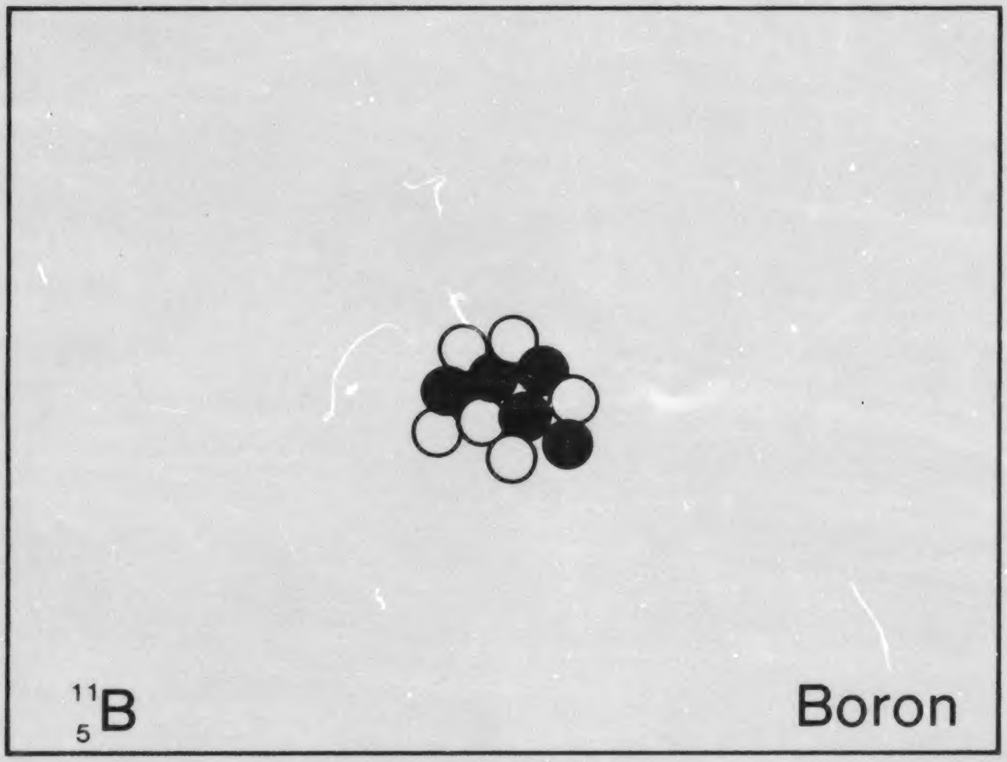
Tell the students that the class is going to diagram the nuclei of some different elements.

Activity

Show the students a sample card whose format resembles the one below. Point out that the names of the chemical elements are often abbreviated in standard symbols when they are written. Point out where the number of protons and the number of protons plus neutrons is written next to the symbol.

Assign each student a number. Each student is to make diagrams of the two nuclei that have his number in the right hand column. So, when the sheets are passed around, each student needs to copy down the symbol, the number of protons, and the number of neutrons for each of two nuclei. The chart is arranged so that each student does one light and one heavy atom. Doing the lighter element first helps to prevent discouragement.

If some students finish early, you can ask them to do an additional nucleus from the list, choosing one that has no student number.



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Lesson
continues.

Most Abundant Isotopes of the 92 Elements

Element	Symbol	Number of Protons	Number of Neutrons	Number of Protons + Neutrons	Student Number
Hydrogen	H	1	0	1	1
Helium	He	2	2	4	3
Lithium	Li	3	4	7	2
Beryllium	Be	4	5	9	4
Boron	B	5	6	11	5
Carbon	C	6	6	12	6
Nitrogen	N	7	7	14	7
Oxygen	O	8	8	16	8
Fluorine	F	9	10	19	9
Neon	Ne	10	10	20	10
Sodium	Na	11	12	23	11
Magnesium	Mg	12	12	24	12
Aluminum	Al	13	14	27	13
Silicon	Si	14	14	28	14
Phosphorus	P	15	16	31	15
Sulfur	S	16	16	32	16
Chlorine	Cl	17	18	35	17
Argon	Ar	18	22	40	18
Potassium	K	19	20	39	19
Calcium	Ca	20	20	40	20
Scandium	Sc	21	24	45	30
Titanium	Ti	22	26	48	21
Vanadium	V	23	28	51	22
Chromium	Cr	24	28	52	23
Manganese	Mn	25	30	55	24
Iron	Fe	26	30	56	25
Cobalt	Co	27	32	59	26
Nickel	Ni	28	30	58	27
Copper	Cu	29	34	63	28
Zinc	Zn	30	34	64	29
Gallium	Ga	31	38	69	30
Germanium	Ge	32	42	74	29
Arsenic	As	33	42	75	28

Most Abundant Isotopes of the 92 Elements

Element	Symbol	Number of Protons	Number of Neutrons	Number of Protons + Neutrons	Student Number
Selenium	Se	34	46	80	27
Bromine	Be	35	40	75	26
Krypton	Kr	36	48	84	25
Rubidium	Rb	37	48	85	—
Strontium	Sr	38	50	88	24
Yttrium	Y	39	50	89	—
Zirconium	Zr	40	50	90	23
Niobium	Nb	41	52	93	22
Molybdenum	Mo	42	56	98	21
Technetium	Tc	43	54	97*	—
Ruthenium	Ru	44	58	102	—
Rhodium	Rh	45	55	100	—
Palladium	Pd	46	60	106	—
Silver	Ag	47	60	107	20
Cadmium	Cd	48	66	114	19
Indium	In	49	66	115	—
Tin	Sn	50	68	118	18
Antimony	Sb	51	70	121	17
Tellurium	Te	52	78	130	—
Iodine	I	53	74	127	16
Xenon	Xe	54	78	132	—
Cesium	Cs	55	78	133	—
Barium	Ba	56	82	138	15
Lathanium	La	57	82	139	—
Cerium	Ce	58	82	140	14
Praeseodymium	Pr	59	82	141	—
Neodymium	Nd	60	84	144	—
Promethium	Pm	61	85	146*	—
Samarium	Sm	62	90	152	—
Europium	Eu	63	90	153	—

Element	Symbol	Number of Protons	Number of Neutrons	Number of Protons + Neutrons	Student Number
Gadolinium	Gd	64	94	158	—
Terbium	Tb	65	94	159	—
Dysprosium	Dy	66	98	164	—
Holmium	Ho	67	98	165	—
Erbium	Er	68	98	166	—
Thulium	Tm	69	100	169	—
Ytterbium	Yb	70	104	174	—
Lutetium	Lu	71	104	175	—
Hafnium	Hf	72	108	180	—
Tantalum	Ta	73	107	181	13
Tungsten	W	74	110	184	12
Rhenium	Re	75	112	187	—
Osmium	Os	76	116	192	—
Iridium	Ir	77	116	193	11
Platinum	Pt	78	117	195	10
Gold	Au	79	118	197	9
Mercury	Hg	80	122	202	8
Thallium	Ti	81	124	205	—
Lead	Pb	82	126	208	7
Bismuth	Bi	83	126	209	6
Polonium	Po	84	126	210*	5
Astatine	At	85	125	210*	—
Radon	Rn	86	135	222*	4
Francium	Fr	87	125	212*	—
Radium	Ra	88	138	226*	3
Actinium	Ac	89	138	227*	—
Thorium	Th	90	139	229*	1
Protoactinium	Pa	91	140	231*	—
Uranium	U	92	146	238*	2

*Radioactive

Notes

Half-Life of Isotopes

Objectives

This lesson contributes to students' understanding of the following concepts:

Any radioactive material is constantly turning into another substance.

The rate of decay of a radioactive substance can be described by the length of time it takes half of any sample of the isotope to decay into some other isotope.

There is no way of predicting when an individual atom will decay.

Vocabulary

half-life

Format of the Lesson

Review nature of radioactive decay

Question: how to describe rate of decay

Graphing to discover the difference between constant and exponential

The pattern of radioactive decay

Introduce popcorn experiment

Perform popcorn experiment

Tally results

Discussing results

Conclusion

Materials Needed

chalkboard

boxes shallow square cardboard boxes, with tops and bottoms. If you can't get square boxes, make rectangular boxes square by cutting off part of the long dimension and restoring the sides with tape. One box per student.

popcorn about one pound of unpopped kernels of corn.

felt-tip pen

activity sheet **Half-Life,** one per student or group.

worksheet **Half-Life Graph,** one per student.

tally sheet one copy of form provided.

Reviewing Radioactive Decay

Review what the students have learned about radioactive decay, perhaps by asking the following sequence of questions.

How can you tell if a substance is radioactive? (ANS: It emits "rays.")

What is happening when a nucleus of a radioactive substance decays? (ANS: Its nucleus gives off something, particles and sometimes radiation.)

Why does a new element appear in a sample of radioactive material? (ANS: Number of protons in nucleus changes during decay.)

How is it possible to have two different forms of the same element, one of which is stable and the other unstable? (ANS: Different number of neutrons in the nucleus.)

Posing the Question

Since a radioactive isotope is constantly changing into something else, a very useful question to ask would be, how long will any piece of the isotope last before all the atoms in it have changed to something else? In other words, what is the rate at which the isotope decays?

A Familiar Example

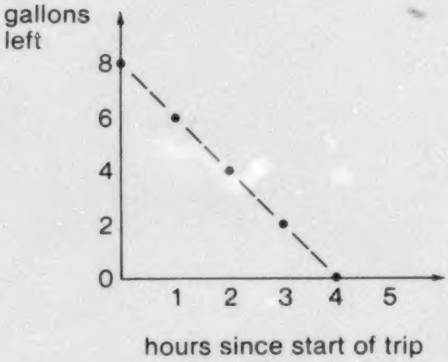
What do we mean by rate?

Let's look at a different example, one that involves a chemical change. We have a car that burns gasoline. Mostly, that's changing gasoline and oxygen to carbon dioxide and water.

Suppose we start a long trip with a tankful of gas, going at a steady 50 miles per hour. (Put figures on the board.) The car gets 25 miles per gallon. That means gasoline is disappearing at a rate of 2 gallons per hour.

$$\frac{\text{50 miles per hour}}{\text{25 miles per gallon}} = \text{2 gallons per hour}$$

Let's make a graph. (Do this roughly on the chalkboard.)



After one hour at 50 miles per hour, 25 miles per gallon, how much gasoline will we have used? (ANS: Two gallons.) How much will be left? (ANS: Six gallons.) (Make the appropriate dot.)

In the next hour? (ANS: Another two gallons.) Leaving how much? (ANS: Four gallons.) (Make the appropriate dot.)

In the third hour? (ANS: Another two gallons.)

OK, notice what's happening. We don't even have to calculate the next hour because we already have a picture of what's happening. All these points lie on a straight line. (Draw the line.) If we extend the line we see that all eight gallons will be gone at four hours.

Is this the way it goes with radioactive decay?

Well, as a matter of fact, it isn't.

The Pattern of Radioactive Decay

How can we tell how many atoms of a radioactive isotope are left — how much fuel is left in the gas tank, so to speak? We can do it with a Geiger counter or other instrument that measures radioactivity by measuring the number of alpha, beta, or gamma rays. The less radioactive substance there is, the weaker the radioactivity will be. (Provided, of course, that the daughter isotope isn't also radioactive.)

Suppose we have an imaginary radioactive substance, icecreamium-66. It decays into slop-66, which is stable.

(Make another graph, saving the gasoline one. Give yourself a good deal of space to the right, because this graph will have to go out to 10 hours.)

We call the radioactivity when we start 100%. After an hour, we measure again and find the radioactivity is only 50% as strong as it was before. Let's indicate that. (Make a dot.)

At 2 hours, we measure again, and we find 25% of the original radioactivity is left.

At 3 hours, 12½%.

At 4 hours, 6¼%.

Let's draw a line through the points.

Is this a straight line? (ANS: No.)

When will it hit zero and the icecreamium be all gone? (ANS: Not sure, or never.)

Maybe we should look at another imaginary isotope, peanutium-50. Remember, even though these are imaginary isotopes, this really is the way radioactive isotopes behave. The only reason I'm using imaginary isotopes is to have the numbers come out evenly.

Peanutium-50

Enter the points on the graph.

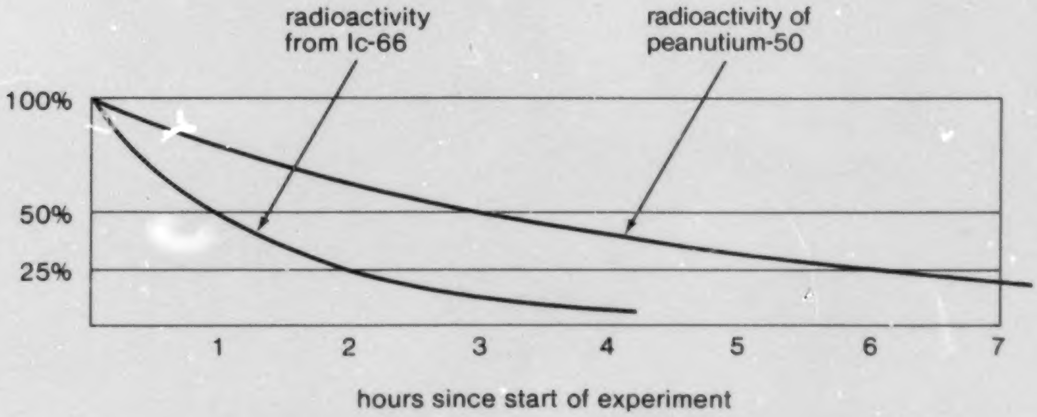
Time	Radioactivity
0 hour	100%
1 hour	79%
2 hours	63%
3 hours	50%
4 hours	40%
5 hours	31%
6 hours	25%
7 hours	20%

Can anyone predict when peanutium will hit 12½%? (ANS: Some students may already perceive that every three hours there is a halving of the activity, and so half of 25% will be reached in another 3 hours, or 9 hours in all. If not, ask leading questions. Call attention to the 50% line and ask how long that took. Then ask what half of fifty is and how much additional time it took to reach 25%. Eventually students will detect the pattern.)

If we know how long it takes half the substance to decay, then it will take that long again for half of what's left to decay. So a way of describing how fast a radioactive isotope decays is to give its "half-life" — the length of time it takes half of any sample to decay.

Why do radioactive substances behave this way? Basically, whether an atom is going to decay or not in the next second is a matter of chance. It might decay now, or it might not decay for another million years. The chances that an atom will decay in the next second are a lot greater with an isotope that has a short half-life like one second than with one with a long half-life like a million years.

Notice this isn't at all like a chemical reaction. At a hot enough temperature gasoline molecules will combine with oxygen atoms just as fast as we can bring them together. There won't be any free gasoline molecules left after a while, unless we run out of oxygen.



Introducing Experiment

To show how chance leads to half-lives, I'd like you to do an experiment. For atoms of a radioactive substance, we'll use kernels of popcorn, which we put in a box and shake. One side of the box is marked with an X, and we'll say the kernels that point to that side have decayed, and take them out. Then we'll graph our results.

Divide the class into groups of no more than three, if you plan to do this as a group experiment. Pass out the two sheets and the materials.

Performing the Experiment

Assist students in getting started.

As groups begin to finish, give them the tally sheet and ask them to enter the results. Select a student (preferably with a calculator) to add the columns while you discuss the experiment.

While the last groups are entering results, invite students to display their graphs.

Discuss the variation in graphs. Point out that this is not due to student's errors, but to the fact that the smaller a sample, the more variation. For example if we wanted to know how often coins come up heads, and each of us only flipped twice to find out, our results would be very different. But if we each flipped ten thousand times, our results would agree closely.

Use the figures from the class totals to construct a graph on the chalkboard or overhead projector.

Then discuss the following questions:

How many trials did it take to use up half the kernels? (ANS: Between 2 and 3.)

How may trials to use up half of the 50 that were left? (Usually occurs between the 4th and 5th trial.)

Notice that the curve from everyone's results is a lot smoother than any one group's curve.

In any sample there are millions and millions of atoms. Would you expect the decay curve measured experimentally to be smooth or not.

A Few Facts

Point out to the students that half-lives differ greatly. Share with them some examples from the following table.

Projects for Independent Investigation

1. Find out how half-life is used to estimate the ages of rocks OR of archeological finds. Make a report to the class.

2. Try plotting the results of the classes popcorn experiment on a sheet of graph paper whose vertical axis (ordinate) is logrithmic.

3. Look at the half-lives of U-235 and U-238. Why do think U-238 is commoner in nature.

Enrichment

Using square boxes gives each kernel a one-in-four chance of "decaying" on any one shake of the box. If the x-ed side is the narrow end of a shoe box the chance of decay is much less than 25%; and much more if the x-ed side is the wide side of a shoe box. By using boxes with different proportions of length to width, you can simulate other decay rates. Ask students to predict if the shape of the box makes a difference. Then have them perform the activity again with boxes of various proportions, recording the decay rate. Can they find a connection between rate of decay and length: width ratio of the box?

Half-Lives of a Few Radioactive Isotopes

hydrogen-3 (tritium)	12.26 years
carbon-14	5730 years
oxygen-13	.0087 seconds
oxygen-14	71.0 seconds
oxygen-15	124 seconds
oxygen-19	29 seconds
oxygen-20	14 seconds
chlorine-36	310,000 years
potassium-40	1,280,000,000 years
vanadium-50	6,000,000,000,000,000 years
cobalt-60	5.26 years
zirconium-96	360,000,000,000,000,000 years
polonium-212	0.000000304 seconds
radon-216	.0000045 seconds
uranium-235	710,000,000 years
uranium-238	4,510,000,000 years
plutonium-244	80,000,000 years
plutonium-246	10.9 days

Half-Life

To do this activity, you need:

☐ a shallow square cardboard box with a cover and a smooth bottom

☐ kernels of popcorn

☐ a sheet of graph paper

Do you have everything you need?

Step One. Mark an X on one of the inside sides of the box.

Step Two. Count out exactly 100 kernels of corn and put them in the box.

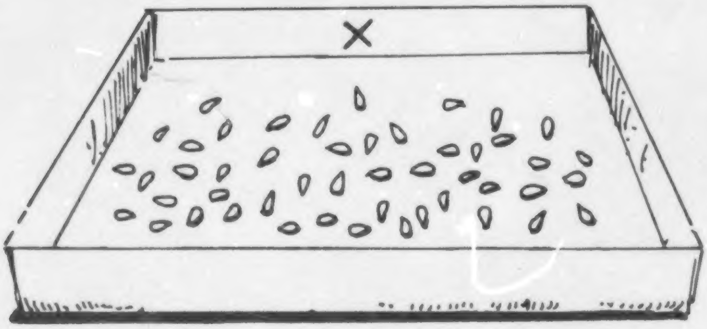
Notice that each kernel of corn has a pointed end. When the corn is in the box, this pointed end will point to the four sides of the box. What do you think the chances are that any particular kernel will point to the side you marked "X"?

Step Three. Put the lid on the box and shake it thoroughly. Put the box back on the table and open it. Remove all the kernels that are pointing to the X-side. If you think some are pointing exactly at the X-side's corners, take half of those out.

Step Four. Count the number of kernels you took out. Enter the number on the graph sheet.

DO NOT PUT THE COUNTED KERNELS BACK.

Repeat Steps Three and Four ten times. Then go on the the graph sheet.

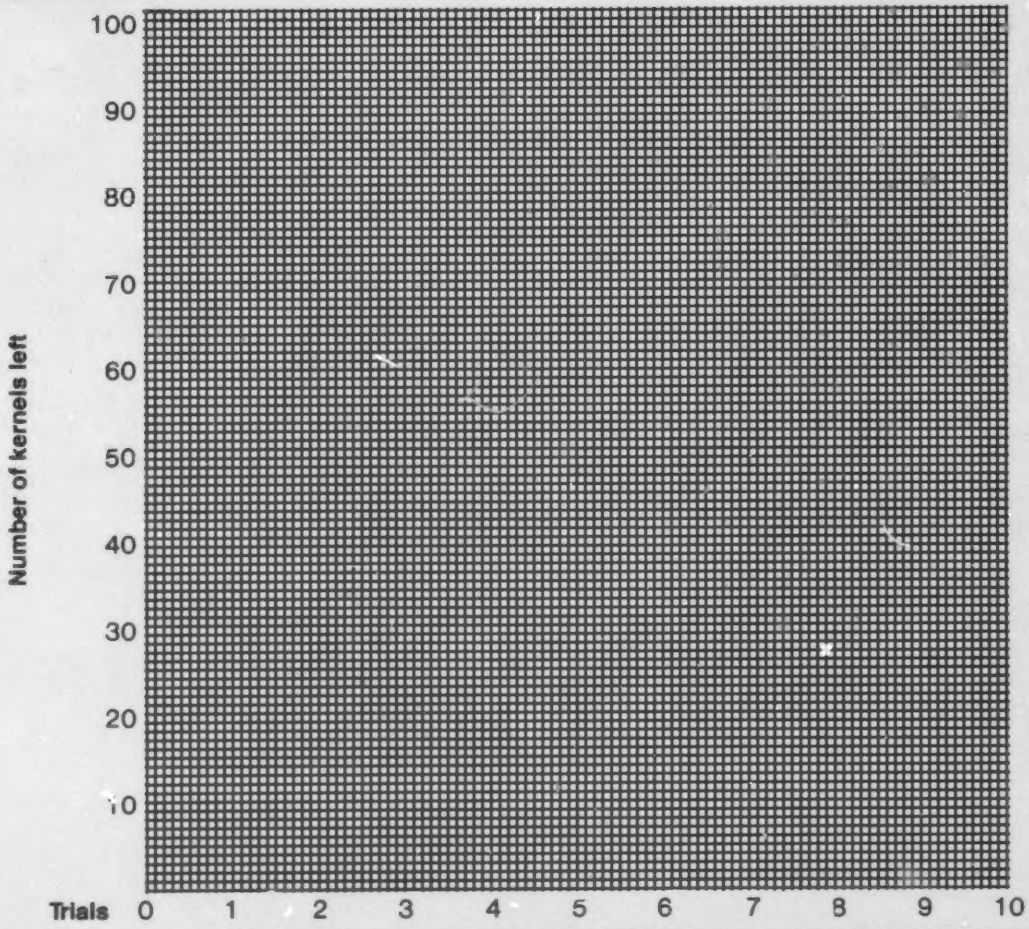


Half-Life Graph

1. Figure out how many kernels were left in the box after each time you shook and counted.

Trial	Started with	Took out	Number left
1	100		
2			
3			
4			
5			
6			
7			
8			
9			
10			

2. Graph your results.



Tally Sheet

	Trials									
Students ↓	1	2	3	4	5	6	7	8	9	10
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
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17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
Total										

Energy from Fission

Objectives

This lesson contributes to students' understanding of the following concepts:

The fission of a uranium atom releases a large quantity of energy.

Mass can be converted to energy.

The energy released from nuclear fission is available as heat.

Format of the Lesson

This lesson is a chalk talk; its main subdivisions are outlined below. With some classes, you may want to perform the indicated calculations. In other classes it may be better just to skip ahead to the results.

Reviewing fission

The case of the missing mass

Converting mass to energy

How much energy in a kilogram?

In what form is the energy released?

Materials Needed

chalkboard

homework, one sheet per student

Reviewing Fission

Review that we've learned a nucleus of uranium-235 can be split into smaller fragments by a neutron. Use the chalkboard to show an equation for what happens.

This shows a nucleus of U-235 and a neutron combining to make a nucleus of uranium-236. The U-236 then fissions. On the right hand side, we've chosen one particular possible set of leftovers to show.

$$^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \longrightarrow ^{236}_{92}\mathrm{U} \longrightarrow ^{95}_{42}\mathrm{Mo} + ^{139}_{57}\mathrm{La} + 7^{0}_{-1}\mathrm{e} + 3^{1}_{0}\mathrm{n}$$

There are lots of other reactions that might occur, but this is one of the most common, ending up in a nucleus of molybdenum (ma-LIB-da-nam), a nucleus of lanthanum (LAN-tha-nam), 7 electrons, and 2 neutrons. This isn't what the uranium nucleus splits into; those original fragments are radioactive and the molybdenum and lanthanum are the eventual products of their decay. The electrons come from that decay; not from the fission of the uranium-236.

See if the Equation Balances

Let's check to see if the equation balances by adding up the numbers of protons and neutrons. (Do the addition on the chalkboard, identifying the figures as you go.)

protons and neutrons in U-235	235
neutron that hit the U-235	1
total	236

Now let's see what we ended up with

protons and neutrons in molybdeum	95
protons and neutrons in lanthanum	139
the two leftover neutrons	2
	236

We started with 236 and we end up with 236, so the equation balances.

The Case of the Missing Mass

So far, we've been talking about the number of protons and neutrons. That is a pretty close approximation of the mass, since we know most of the mass of an atom is in the protons and neutrons of the nucleus. But as a matter of fact, we don't have to depend on counting protons and neutrons to determine the mass of the atom; we can actually measure it experimentally. We won't go into how you can do that, because it's complicated, so you'll just have to take my word that there is a way.

When we do this for the nuclei in this equation, we find out something really surprising.

For convenience, the unit we're going to use to measure the mass of the nuclei is the atomic mass unit, or amu. One atomic mass unit is defined as one-twelfth of the mass of an atom of carbon-12. So the mass of one proton or neutron is pretty close to one amu.

So, first let's add up the mass of what we started with. These are all masses determined by experiment. (Do the addition on the chalkboard.)

mass of the nucleus of U-235	235.0439 amu
mass of one neutron	1.0087 amu
	236.0526 amu

Now let's add up the mass of what we ended up with. (Ask students to identify products; you enter the mass on the board.)

mass of molybdenum nucleus	94.9058 amu
mass of lanthanum nucleus	138.9061 amu
mass of 7 electrons each .00055 amu	.0039 (rounded off)
mass of 2 neutrons	2.0174
making a grand total of	235.8332 amu

What do you notice about the two totals? (ANS: We started with more than we ended up with.)

Let's see how much mass we seem to have lost.

236.0526
-235.8332
.2194 amu (round it off to .219 amu)

Because amu are so unfamiliar, let's change this into grams.

1 amu = 1.6604×10^{-24} grams

Notice the exponential notation. I'm using this because this is such a very, very small mass. This part of the equation ("x 10^{-14}-") means multiply by 1 over ten with 24 zeros after it. So you can see it's very, very small.

.219 amu = $.219 \times 1.6604 \times 10^{-24}$ grams
= $.3636 \times 10^{-24}$ grams
(shifting the
decimal point) = 3.636×10^{-24} grams

This is a very, small difference, but a real difference. Part of the mass of the uranium nucleus we started with is missing!

Now, how can this be possible? You know matter doesn't just disappear. (At this point, students themselves may point out the interchangeability of matter and energy. If they do, compliment them and explain more fully.)

Einstein's Famous Equation

How many of you have every heard of this equation? (Put it on the board.)

$$E = mc^2$$

This is probably the world's most famous equation. It tells us that matter and energy are interchangeable, and how much matter is equal to how much energy. "c" is the speed of light. "m" is the mass of something sitting still. "E" is the amount of energy that mass is equivalent to.

Let's figure out how much energy the missing mass from the uranium nucleus would be equal to.

We will work in joules, so

energy in joules = (kilograms) x (speed of light in meters per second)^2

We are missing 3.636×10^{-25} grams. Let's change that to kilograms by dividing by a thousand. To do that, we need only to substract 3 from the exponent.

3.636×10^{-25} grams = 3.636×10^{-28} kilograms

The speed of light is 2.998×10^{8} meters per second, so

energy in joules = $3.636 \times 10^{-28} \times (2.998 \times 10^{8})^2$

squaring the speed of light (Notice that we only keep the four significant figures we started with. We could get lots of extra digits but they wouldn't mean a thing, because we only knew the speed with a precision of four significant digits in the first place.)

energy in joules = $3.636 \times 10^{-28} \times (8.988 \times 10^{16})$
= $3.636 \times 8.988 \times 10^{-28} \times 10^{16}$
= 32.680×10^{-12}

(rounding off) = 3.2×10^{-11} joules

Let's convert this to a more familiar unit, like calories.

1 joule = .239 calories
3.2×10^{-11} joules = 7.6×10^{-12} calories

How Much Energy in a Kilogram?

This doesn't look like a lot, does it? But remember, this is the energy from just one atom. In a kilogram of U-235 there will be about 26 x 10^{-24} atoms. If all of these atoms fissioned we would get (2.6 x 10^{24}) atoms x (7.6 x 10^{-12}) calories per fission or about 20 x 10^{-12} calories per kilograms of U-235.

In comparison, burning

one kg of coal gives –	6.9 x 10^6 cal
one kg of gasoline –	10.5 x 10^6 cal
one kg of natural gas –	13 x 10^6 cal
one kg of wood –	3.3 x 10^6 cal

So we see that you could get about 10^6, or a million times more energy from the fission of a kilogram of U-235 than from the combustion of fuels. In actual practice, however, we can't get this much energy from fission — and, do we get the energy in a useful form?

In What Form is the Energy Released

Here are some ways the energy of fission is released.

energy of motion of new nuclei	82%
energy of motion of neutrons	2%
gamma rays	3%
Beta particles (from decay of fission fragments)	3%
gamma rays (from decay of fission fragments)	3%
neutrinos (from decay of fission fragments)	5%

(doesn't add up to a 100% because of rounding off)

The neutrinos just escape into space. But everything else interacts with the surrounding atoms, and the eventual result is an increase in the random motion of surrounding atoms — in other words, an increase in heat. So basically heat is the form of energy we can get from nuclear fission — at least at the present stage of our knowledge.

Teacher Background

In this lesson, we used conversion of mass to energy to estimate the energy released in the fission of a single atom. But the amount of energy released can be estimated in several other ways, all of which are in good agreement.

For example, the concept of binding energy could be used. The mass of an atom, determined experimentally, is always less than the mass of the individual neutrons, protons, and electrons that could be assembled to make the atom. This "missing" mass represents the amount of energy which would be released if we could bind together protons, neutrons, and electrons to make the atom. To break the atom down into its components, we would have to supply this energy.

The binding energy of the uranium nucleus is smaller than the sum of the binding energies of the fission products; fission releases this difference.

A third way of estimating the energy released per fission is to calculate the electrical repulsion between the two positive fragments as they start to fly apart.

If You Were Nuclear-Powered...

Chances are that every day you eat about 3000 Calories (food Calories, or kilogram calories). That is equal to about 12 million joules.

Which chemical element in your food is most important in providing you with energy? Let's say carbon. Your body gets energy by oxidizing carbohydrates.

But suppose your body could get energy by converting mass (of carbon atoms) to energy. How many carbon atoms per day would you need?

A single carbon atom (carbon −12) has a mass of 2×10^{-26} kilograms. Calculate how many of these atoms you would need to convert to energy to equal the 12 million joules you get each day from food. Part of the calculation has been done for you; complete it by filling in the boxes.

1. How much energy from one carbon atom?

$$E = mc^2$$

energy in joules in one carbon atom = (mass of 1 carbon−12 atom in kg) x (speed of light in meters per second)^2

$$= (\underline{\quad\quad} \times 10^{-26} \text{ kilograms}) \times (3 \times 10^{8} \text{ meters per second})^2$$

$$= \underline{\quad\quad} \times 10^{-26} \times 9 \times 10^{16}$$

$$= \underline{\quad\quad} \times 9 \times 10^{-26} \times 10^{16}$$

$$= \underline{\quad\quad} \times 10^{-10}$$

II. How many atoms per day?

You need 12 million joules each day, (12×10^{6}), so

$$\text{number of atoms needed} = \frac{\text{joules you need per day}}{\text{joules from converting 1 carbon atom to energy}}$$

$$= \frac{12 \times 10^{6}}{\underline{\quad\quad} \times 10^{-10}}$$

$$= \frac{12}{\underline{\quad\quad}} \times 10^{6} \times 10^{10}$$

$$= \underline{\quad\quad} \times 10^{16}$$

I would need ______________________________ carbon atoms per day.
(This would make a piece so small you couldn't even see it, with a mass of about

$$\frac{1}{100{,}000{,}000{,}000 \text{ gram}}$$

Notes

Unit Five
Renewable Energy Sources

Narrative Overview

Why We're Teaching This

The United States faces an energy transition—away from imported petroleum and, in the long run, away from depletable fossil fuels. It seems likely that in this long run we will not be turning to one or two new energy sources, but to a mixture adapted to local needs and resources. To a much greater degree than our two earlier energy transitions, this transition will require separate decisions by millions of persons—homeowners, car and appliance buyers, business people, city officials—all of us. Today's students, tomorrow's adults, need to be prepared to make these decisions.

In this unit we are not trying to predict what our future energy sources will be. Rather, we help students see that for most purposes there are workable alternatives to the inevitably exhausted fossil fuels. We will give students experiences in figuring out how at least one type of alternative energy source works and in using economic and other factors in choosing between alternative energy sources **under a particular set of conditions** (their own circumstances).

Direct solar and biomass were chosen as the two examples for study because they excite the most enthusiasm among teachers and students, and because students can easily experiment with them.

What We'll Teach and How

Students perform a quantitative investigation using a tin can as a flat plate collector. This demonstrates that thermal energy is readily available from sunlight, provides a rough idea of how much, and suggests to students a wide range of further experiments in which they try to maximize the amount of thermal energy they can get from their collector. Students relate the construction of their collector to that of a commercial solar water heater, and evaluate its performance.

To exploit the energy of sunlight efficiently, one must be aware of how the direction the sunlight comes from changes during the day and year. Through activities with a compass and an astrolabe they make, students learn the meaning of altitude and bearing, and use them to specify a position in the sky. They then map the shadow cast by a stick for a day, and use the data to construct a graph of bearing and altitude which shows the sun's movement during that day. Now that they know how such a chart is constructed and the meanings of the quantities graphed, students are given a chart for their latitude showing the sun's position over the course of an entire year. This chart is used in student activities in which they estimate the size of a horizontal overhang needed to shade a south-facing window in summer, but not in winter.

Is it possible to obtain higher temperatures from sunlight? Students experiment with concentrating light. You may wish to follow that lesson by building our version of the ubiquitous solar hot dog cooker, using it to illustrate how quantitative information is used in attacking engineering problems.

Lastly, a few activities are provided that demonstrate how energy is stored in biomass.

The variety of renewable energy sources is so vast that it is impossible to take up each one as a class topic. At the same time, a great deal of coverage of these sources has appeared in the popular press. This creates an ideal opportunity for student research reports. Students may chose an energy-related topic from a list provided. To give the students a clear idea of what would constitute an adequate report, as well as help in making such a report, the resource book provides for each topic:

- a set of questions covering factors that would need to be discussed in a presentation on this topic
- a student bibliography, consisting mainly of recent articles from the popular press

- a workable outline*
- teacher bibliography, the same as the students' but with reading levels marked, to make it easier to provide guidance to students of differing abilities
- teacher grading sheet, which provides a convenient way of indicating the adequacy of various aspects of the report

*We suggest the teacher not give this crutch to students unless in the teacher's judgment the student is unable to begin without it. Also left to the teacher's discretion is whether the reports should be oral or written. We suggest reports first be given orally, the marked grading sheet given to the student, and the student given the option of preparing a written version of the report correcting defects indicated on the grading sheet, and that the grade on the written version replace that of the oral version.

[This overview is provided to give the reader some idea of the sequence. The present edition is a sample of the activities and lessons mentioned. If you have a particular interest in any activities mentioned that have not been included, write to us. Mention which activity you wish and the what subject and grade level you teach. Promise to provide a full report on the results should you decide to try the activity with your students, and we will send you the current draft version.]

Collecting Heat from Sunlight

Note

This lesson is best done on a bright, sunny day. Heat will be gained on cloudy days, but the effect is much less dramatic.

Objectives

This lesson contributes to students' understanding of the following concept:

Light absorbed by an object is converted to thermal energy.

Materials Needed

pint screw-top cans one for each group. Pint cans work better than quart cans because the ratio of surface area to volume is greater, producing a more dramatic rise in temperature. If you cannot scavenge enough cans and cannot locate a local source, a national distributor is Freund Can Co., 180 W. 84th St., Chicago, Illinois 60620. Their can #1907 is 90¢ apiece, with a minimum order of 60 cans. If a case of 252 is purchased the price drops to 45¢ apiece.

Paint one side of the can flat black with ordinary wrought-iron flat black.

thermometers, Celsius one per group.

rocks or something to prop up the cans so that the black surface is at right angles to the sunlight.

water at room temperature.

graduated cylinder or measuring cups graduated in milliliters.

activity sheet **How Much Heat Can We Get From Sunlight?**, one per group.

worksheet **Calculating How Much Heat Can Be Obtained From Sunlight,** one per group.

Format of the Lesson

Discuss usefulness of low-temperature heat

Begin the investigation

Go outside (allow approximately 15 minutes)

Return, complete worksheets (if you've accidentally run out of time, assign the worksheets as homework)

Discuss to establish significance of obtaining heat from sunlight

CONDUCTING THE LESSON

Prior to class, prepare the cans and other materials.

Opening Discussion: Do We Need Low-Temperature Heat?

Suppose that by low-temperature heat we mean heat used to raise the temperature of things not quite to the boiling point of water. Do we use low-temperature heat in our homes? (ANS: Yes.) For what? (ANS: Water heating, space heating, warming leftover coffee, etc.). What energy sources do we use to get low-temperature heat in our homes? (ANS: We burn natural gas, we burn heating oil, we use electricity.)

Tell the class that they will do an investigation to discover whether sunlight could be used as an energy source to provide low-temperature heat.

Beginning the Investigation

Divide the class into groups. Give each group a can, a copy of the activity sheet **How Much Heat Can We Get From Sunlight?** and a copy of the worksheet **Calculating How Much Heat Can Be Obtained From Sunlight.** Point out the source of water and the other materials needed.

Tell students to complete the first four steps on the activity sheet.

Going Outside

Take the class outside and complete activity. If only a few students have watches, you may wish to do the timekeeping yourself, announcing "go," "stop," and the elapsed time.

Inside Again: The Results, and What Do They Mean?

Complete the calculations. You may stop the calculations when all groups have completed Section IV. Compare answers. Why is there a range?

Would this way of obtaining heat be useful for any of the purposes we discussed at the beginning of the class? Which purposes?

Investigations for Further Study

The tin-can-as-solar-collector procedures used in this lesson can be used as the basis for a week of investigation. Here are a few avenues worth exploring. If you choose not to use these as classroom activities, you may wish to suggest them to students as projects for independent study.

1. How much difference does the tilt of the collector make? For example, what percent of the heat collected by a can perpendicular to the sun's rays will a vertical can collect? How do different angles compare in the amount of heat they absorb? If you can't change the tilt of a collector during the day (as the altitude of the sun changes), what is the best angle for the collector?

2. What difference, if any, does the color of the collector make? Paint cans different colors. Many students know black absorbs more light than white. But how great is the difference, expressed as a percentage?

3. Make a graph showing the changes on the temperature of the water in the can by taking readings every minute. Eventually the temperature reaches a plateau. Why?

4. Try different ways of insulating the cans. Beadboard held together with packing tape is cheap and effective. Try glazing the collector with Saran wrap. How does each of these steps affect the efficiency of the collector? Be quantitative.

Projects for Independent Investigation

1. Every solar collector is also an emitter of radiation, since every object whose temperature is higher than absolute zero is continually giving off radiant energy.

You have seen that a surface painted black may absorb more light than a surface painted another color. Is it possible that a surface painted one color will emit more radiant energy than a surface painted another color? (For a fair comparision, the two surfaces would have to be at the same temperature.)

Is it possible to have a surface that is a good absorber of sunlight but a poor emitter of radiation at the temperature it reaches when it is warmed by sunlight?

Devise some experiments to test your opinions. Carry out the experiments.

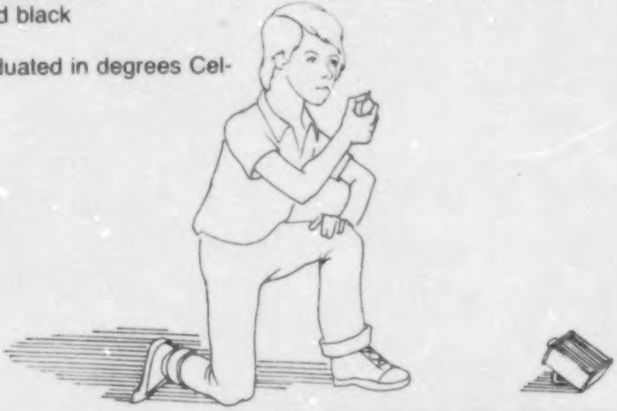
(Hint to the teacher: Another way of setting up an investigation of this topic, which is quite important in the design of solar collectors, is to buy a piece of Maxorb® Solar Foil from Kalwall (P.O.Box 237, Manchester, N.H. 03105). Ask students to compare its effectiveness with that of aluminum foil painted black. How can they account for the difference observed?)

How Much Heat Can We Get From Sunlight?

Is it possible to get enough heat from sunlight to make the trouble and expense of collecting it worthwhile? In this investigation, you will obtain heat from sunlight, and then *measure* the amount of heat you obtained. To do the investigation, you will need:

- ☐ worksheet called *Calculating How Much Heat Can Be Obtained from Sunlight*
- ☐ pint screw-top metal can, with one of the large sides painted black
- ☐ thermometer, graduated in degrees Celsius
- ☐ graduated cylinder
- ☐ water
- ☐ ruler, graduated in centimeters
- ☐ watch or stopwatch, with a sweep-second hand or digital readout in seconds

Do you have everything you need?



Procedure

Step One: Look over this sheet and the worksheet.

Step Two: Measure the front of the can. Enter the measurements on your worksheet.

Step Three: Using the graduated cylinder to measure the amount of water, fill the container. Leave a small airspace. Record the volume of water on the worksheet.

You learned earlier that one milliliter of water has a mass of almost exactly one gram. What is the mass of the water in your container?

Step Four: Use your thermometer to measure the beginning temperature of the water. Record the measurement on your worksheet.

When all the groups are ready, your teacher will take the class outside. Let the teacher know your group is ready by raising your hand.

Step Five: Place the can in full sunlight. Prop it up so that the black surface is perpendicular to the sun's rays. Start timing immediately. Enter the time when you began on the worksheet.

Step Six: Let the can sit for exactly 15 minutes. At the end of 15 minutes, remove the top of the can and measure the temperature of the water. Enter the temperature on the worksheet.

Step Seven: When your teacher says that all groups have finished, return to your classroom with the rest of the class. Put the materials back where they belong.

Step Eight: Do the calculations on your worksheet.

Calculating Heat From Sunlight

I. Calculate How Many Calories the Water Gained.

Remember the formula for calculating calories:
(temperature difference in degrees Celsius) X (mass of water in grams) = calories

Temperature of water at end = ____ degrees Celsius

Temperature of water at beginning = ____ degrees Celsius

Temperature difference = ____ degrees Celsius

(Remember that 1 milliliter of water has a mass of 1 gram.)

Volume of water ≅ ____ milliliters

≅ mass of water in grams = ____ X ____ grams

calories

II. How Long Did It Take?

Time you ended = ____ minutes ____ seconds

Time you began = – ____ minutes ____ seconds

Length of time can was exposed 15minutes 0 seconds

15 minutes is equal to ____ hour

You measured the number of calories the can gained in 15 minutes.
Predict how many calories the can could gain in 1 hour.

____ calories per hour

III. How Large A Collecting Area Did You Use?

Height of can surface = ____ centimeters

Width of can surface = X ____ centimeters

Area of can surface = ____ square centimeters

IV. Rate

Now you have the information you need to calculate the rate at which we can get low-temperature heat from sunlight. If we know the rate, we can calculate how big a collector we would need to get a given number of calories in a given amount of time.

You got ____ calories

in 1 hour from a surface area of ____ square cm

____ calories per square cm per hour

V. A typical dishpan contains 20 liters of water. Water as it comes from the water main typically has a temperature of about 13°C. Hot dishwater, as hot as hands can stand, is about 42°C. If a collector had the same efficiency as the tin can in your experiment, how big a collector would you need in order to heat enough water in half an hour to do the dishes?

The Sun's Movement

Why This Sequence of Lessons?

A solar collector absorbs the most energy per square foot when it directly faces the sun. Yet the position of the sun changes during the day and also with the seasons. Which way should collectors face? How should houses be built to keep out hot summer sun yet admit winter sun? We also need to understand how the direction of sunlight changes to make greater use of daylight for lighting rooms in our buildings. Movement of the sun is the key to exploiting the energy of sunlight efficiently.

Objectives

As a result of this sequence of lessons, students will be able to:

Describe angles in degrees

Use a compass to find a bearing angle

Use an astrolabe to find the altitude angle of the top of an object

Use bearing and altitude to specify a position in the sky

Format of the Lesson

Review angles

  practice use of protractor

Bearing

  discuss naming of directions

  use compass to measure bearing angles

Altitude

  discuss directions in 3 dimensions

  make astrolabe

  measure altitude angles

Materials Needed

protractor one per student

magnetic compasses preferably including some of the "orienteering" type marked with degrees. If you only have laboratory compasses, use a protractor to mark off a compass rose in degrees on a 3x5 card. Cut a hole the size of the compass face in the card and tape the compass in the hole, its face flush with the surface of the card.

3x5 white index cards about two per student

thread one spool of heavy black or brown thread

nuts one per student, 1/4-20 or larger

worksheet **Finding Your Bearings,** one per student

worksheet **Making an Astrolabe,** one per student

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CONDUCTING THE LESSON

Introducing Angles

Determine whether your students are familiar with the measurement of angles. Briefly review their measurement. On the chalkboard, draw a variety of 30° angles: one with long legs and its vertex up, one with small legs and the vertex to the right, one with the vertex down, and so on. Point out that when lines meet, they make an angle. Ask what is the same about these angles. (Ans: Size of the angle.) Agree that all the angles are the same size. How can we state what size the angles are? Some students may mention degrees. If not, draw a circle on the board and divide it into quarters. Ask students to describe the size of the four angles formed. If the students do not volunteer it, point out that each is called a 90° angle. If we divide one of these angles in half, how big is the resulting angle? (45°.) How big is an angle that makes a straight line (180°.) Can we have an angle bigger than 180°? How many degrees are there in an angle the size of a full circle (ANS: 360°.)

Demonstrate how a protractor is used to measure an angle. Have the students work in groups of three or four to practice this skill. One way of doing this is to have each student mark an angle on a sheet of paper and pass it to the next student, who measures it, writes down the number of degrees next to the angle, draws a new angle, and passes the sheet on to the next student, who repeats the process. Eventually the sheet will come back to the student who drew the first angle on the sheet. She should check the measurement made of the angle she drew and pass the sheet on. In the end, every angle will have been measured twice.

Compass Bearings

Ask the students how we describe directions. Following students' instructions, construct a compass rose on the chalkboard, with north at the top. Include northeast, southeast, etc. After the rose is complete at this level of detail, ask the students the name of the direction that is halfway between northeast and east, indicating this direction by a line on your drawing. (ANS: East-northeast.) What do you think we call the direction that is halfway between east-northeast and northeast? (ANS: Doubtful if any students will know this — northeast by east.) Things are getting complicated aren't they? So people invented an easier way. They used degrees. We can call North zero degrees. Draw a line from the center of the compass to North and mark it 0°. Draw another line from the center to East. What is the size of the angle made? (ANS: It's a right angle, or a 90° angle.) So we can call East 90°. In the same way, by measuring the angle from north, we can give a name in degrees to any direction. Give degrees names to the other directions (south, west, northwest, etc.) on your compass rose.

Leaving the drawing on the chalkboard, pass out the worksheet **Getting Your Bearings.** Pass out compasses. If you are familiar with magnetic declination, you may wish to discuss it; otherwise, it can be safely omitted. Complete and discuss the worksheet in class. The outside work is brief and may be done independently during a lunch break or after school.

Measuring Angles from the Horizon

Review the fact that the class has learned to measure angles using north as a reference, and so are able to specify any direction as an angle. But compass directions are all horizontal. Use your arm as a pointer and act out the directions. We don't live in a flat world. How can we describe three-dimensional directions, like the direction of an airplane or a star? We can do that by measuring angles from the horizon. A compass can't do that; we will need another instrument.

In class, distribute the materials needed to make the astrolabe and the worksheet **Making an Astrolabe.** Have each student make his own instrument.

CAUTION STUDENTS NEVER TO POINT THEIR ASTROLABES AT THE SUN. Permanent damage to the eye can be done by looking directly at the sun.

Projects for Independent Investigation

1. If there is a student who is proficient in orienteering contests, ask her to describe the competition to the class.

2. What role have angles played in navigating ships? Prepare an oral report on the development of navigation from Roman times to the 18th century.

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Lesson
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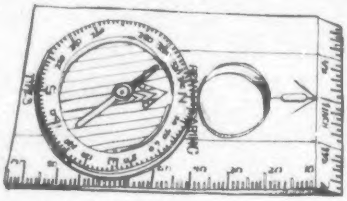
Getting Your Bearings



To do this activity, you will need a compass marked with degrees.

How many degrees in a full circle? ____________

How many degrees in a half of a circle? ____________

How many degrees in a quarter of a circle? ____________

Imagine you are standing facing the north, with your arms lifted to shoulder level and pointing in opposite directions.

What directions does your right hand point? ____________

What direction does your left hand point? ____________

What direction is to your back? ____________

Turn the compass so that the north end of the needle points to zero degrees. (If you know the magnetic error for your location, your teacher will show you how to correct it.) In taking bearings the rule is that north is always zero degrees.

What bearing will south be? ____________ degrees

What bearing will east be? ____________ degrees

What bearing will west be? ____________ degrees

What bearing will southwest be? ____________ degrees

How many degrees difference is there between east and south? ____________ degrees

How many degrees difference is there between south and west? ____________ degrees

How many degrees difference is there between west and south? ____________ degrees

How many degrees difference between west and east? ____________ degrees

Pick two objects in your classroom. Write their names below, and then measure their compass bearings from your seat. Subtract to find the angle between them.

Objects	Bearing
____________	____________ degrees
____________	____________ degrees

The size of the angle between the two objects is: ____________ degrees

Outside Work

How many degrees difference in bearing is there between the two tallest non-moveable things you can see from the school steps?

Thing One: ______________________ degrees

Thing Two: ______________________ degrees

Angle between them: ______________________ degrees

From the school flagpole, how many degrees difference in bearing are there between the easternmost and the westernmost edges of the school building? ______________________ degrees

Making an Astrolabe

To do this, you need:

☐ smooth dark string, such as a foot of buttonhole twist

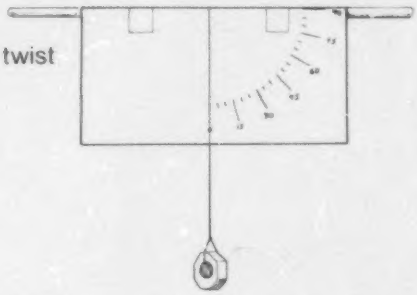
☐ large nut (as in a nut and bolt)

☐ tape

☐ a drinking straw

☐ a protractor

☐ a sheet of stiff white paper – an index card is too flimsy. You may need to tape a sheet of white paper to a piece of heavy cardboard. A size of 8 cm by 15 cm inches is about right.



Procedure

Step One: Draw a line across the middle of the paper. Put a dot in the middle of the line. Take this dot as the center of a circle and using your protractor draw a semicircle and mark it off in degrees from ninety to zero, as shown in the drawing.

Step Two: Tie the nut to one end of a piece of string. Punch a small hole where the dot is and thread the string through it, so the nut hangs on the side of the cardboard where the degrees are. A good way to do this is to use a heavy sewing needle. Tie a knot on the other side of the cardboard, or use glue, so that the string doesn't slip through.

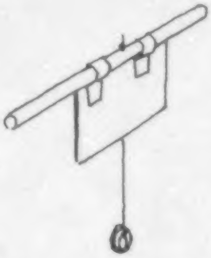
Step Three: Tape the drinking straw exactly along the line you first drew, so that it sticks out. Put your name on your instrument.

Using the Astrolabe

Look through the straw at some object in the sky, or just something tall.

NEVER LOOK DIRECTLY AT THE SUN!

Let the nut hang freely. While you are looking, clamp the string against the paper with your thumb. Then see where the hanging string crosses the degree markings. Read the number of degrees from the scale. That is the altitude of the object in degrees.



Questions

Suppose you were looking at the edge of the sea on a clear day. This is the horizon.

What altitude would it have? ______________________ degrees.

What altitude would directly overhead be?
(This is called the zenith). ______________________ degrees.

What altitude would half-way between
the horizon and the zenith be? ______________________ degrees.

From your bedroom window, what object
was the greatest altitude? ______________________ degrees.

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Making a Shadow Graph

Objectives

This lesson contributes to students' understanding of the following ideas:

In the northern hemisphere, the sun is due south when it is highest in the sky.

Sun time and clock time do not exactly coincide.

The sun's altitude changes in a predictable way during a day.

Format of the Lesson

The activity in this lesson must be done outside on a sunny day during the morning, noon, and afternoon. Every student or group of students can make its own observations, or you can choose to do a demonstration for the whole class. If the students will not be using the equipment, it is somewhat easier to use a nail as the vertical rod, since it can be bent a little to adjust it to be perpendicular to the board. The straws, while less hazardous, can't be adjusted to a new angle to compensate for errors in drilling the holes.

In the classroom before the activity:

Discuss the value of recording observations of natural phenomena.

- Show the students a sample of the apparatus.
- Go over the directions on the worksheet.
- Arrange a time for conducting the observations.
- Construct the apparatus.

Materials Needed

boards one for each student. Wooden boards, pieces of plywood no less than 1/4" thick or, best of all, plastic beadboard ($1.75 for a 4' x 8' x 1" sheet) can be used. Beadboard or other usable insulating boards can often be scavenged as discards from building sites. Cardboard isn't thick enough to hold the straw in a vertical position. In the middle of the board, a hole should be drilled exactly perpendicular to the board and just the size of the straw. Use a drill press or a Portalign R (see your teacher).

straws as small in diameter as possible; one for each student. The round kind used as drink stirrers are best.

shadow graph form one sheet for each student. These can be reproduced from the master provided.

bubble-level one.

square or protractor one.

compass at least one.

tape one roll.

watch or clock at least one.

protractor one per student.

Observations:

In class, after the observations:

- Display all the sheets on the bulletin board.
- Discuss their meaning.

Following a Shadow

How can we record the direction of the sun as the day goes by? We shall try to do this with an instrument we'll construct. This instrument looks something like a sundial, but it doesn't tell time.

Note: You must begin this activity early in the day — no later than 10:00 a.m. and the earlier the better.

Step One: First, we need something flat with a vertical rod in the middle. Your teacher will have talked with you about this. We'll suppose it is a board with a short straw sticking straight up in the middle.

With a square or protractor, check to be sure the straw really is perpendicular to the board.

Your teacher will give you a sheet of paper with circles marked on it. On the paper is a line; the straw has to stick out above the surface of the board exactly as far as this line is long. Check to be sure that it does. Cut off some or add a new straw if necessary.

Step Two: Poke a small hole in the paper at the exact point where the crosshairs meet. This point is the center of the circles on the shadow graph paper.

The hole should be just big enough to let the straw through. Slide the paper over the straw and down onto the board. Center the straw exactly in the center of the crosshairs. Then tape the paper to the board. If your board is small, you may have to tear away some of the paper so that you can see some board to tape the paper to.

Step Three: Put the board outdoors in a place where it will not be in the shade at any time during the day. Using the compass, turn the board until the arrow marked south on the board points directly south.

(If your class has discussed magnetic declination, correct for it.)

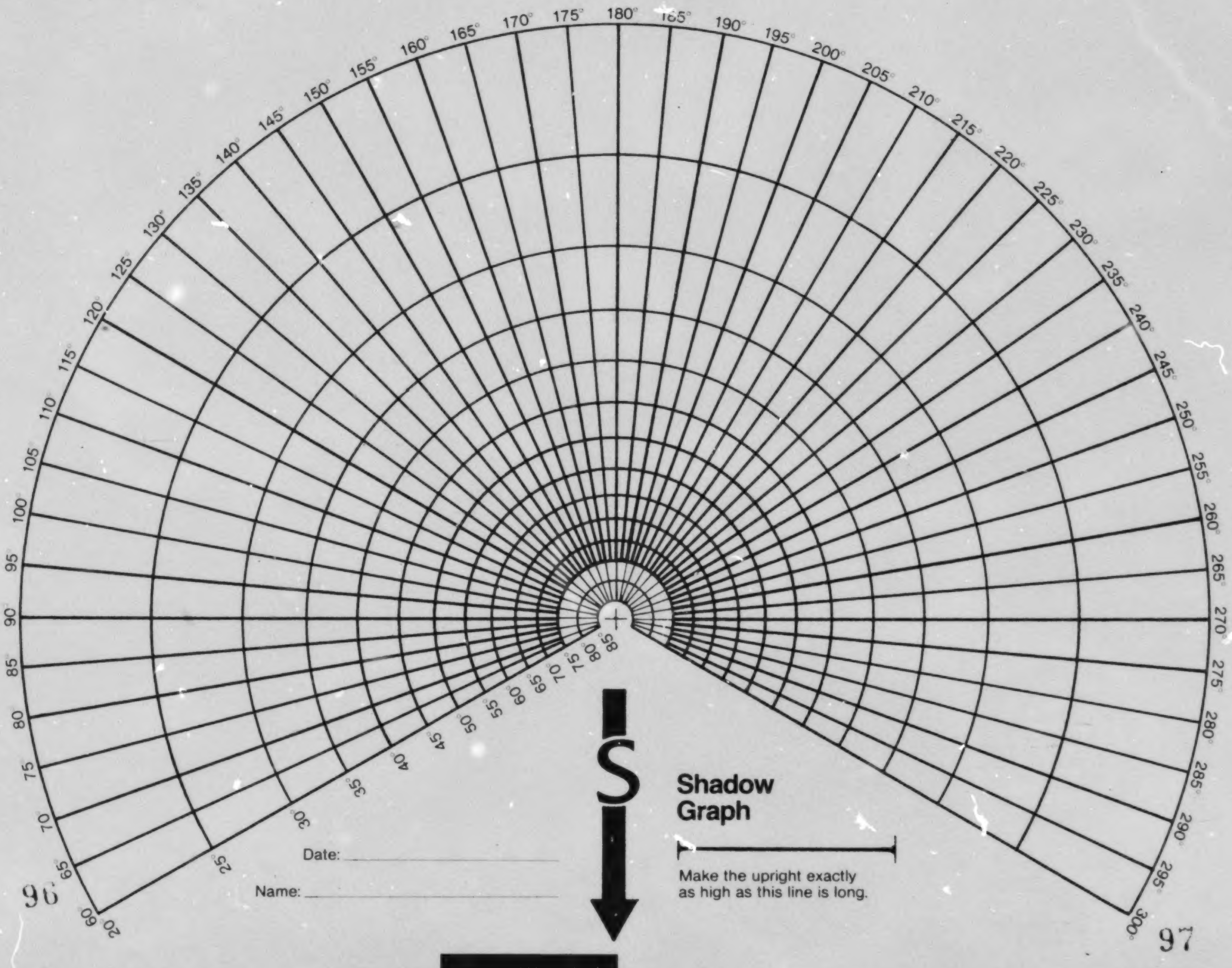
Now level the board level. If possible, use a bubble-level to make sure the board is level. Finally, brace the board as well as you can so it won't move accidentally during the day. (After bracing it, you may want to check again to be sure the arrow is pointing south and the board is still level.)

Step Four: The straw casts a shadow on the paper. Being very careful not to move the board, make a little dot at the end of the shadow. Draw a circle around it so you can see it, like this: (. 10:00 am). Next to the circle, write what time it is.

Step Five: Continue doing this as often as every fifteen minutes for the rest of the day. (Every hour is okay. Maybe you can do it between periods.)

Step Six: At the end of the day, sight along the straw at two different landmarks and make marks on the paper to show where the landmarks are. Write the name of the landmark next to the mark. Then remove the paper from the board.

Step Seven: Draw a smooth curve through all the dots you have made. Write your name and date on the paper and turn it in to your teacher.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Date: ______________________________

Name: ______________________________

Shadow Graph

Make the upright exactly as high as this line is long.

Examining the Shadow Graph

When and Where is Noon?

Answer these questions by studying the graph on which you recorded the moving shadow.

1. If the sun were directly overhead, where would the end of the shadow be?

____

Was the sun ever directly overhead on the day you made your graph? __________

2. One way of defining noon is to say that it is the time when the sun is highest in the sky. This is called solar noon. As the suns gets higher in the sky, what happens to the length of the straw's shadow? ______________________________

____

3. Mark the place on your sheet where the end of the shadow was when the shadow was shortest. When the sun was in this position, it was solar noon. About what time was it then on the clock? ______________________________

Look at a map of time zones. What is the easternmost city where it is the same time as it is where you live? ______________________________

What is the farthest west city where it is the same time as it is where you live?

____

Can the sun be overhead at both these places at once?

____

Bearings

4. The sun is highest in the sky when it is due south. So when the shadow of a vertical stick is shortest, the shadow is running exactly north and south.

Draw a line on your shadow graph from the bottom of the straw to the point where the end of the shadow was when the shadow was shortest. This was the north-south line when you were making your observations.

Compare the line with the arrow pointing south, which is printed on the paper. You used this arrow to line up the shadow graph. After you set the paper, did the south arrow on it point exactly south?

If not, about how many degrees were you off? ______________________ degrees.

5. At sunrise and sunset, where do you think the end of the shadow would be?

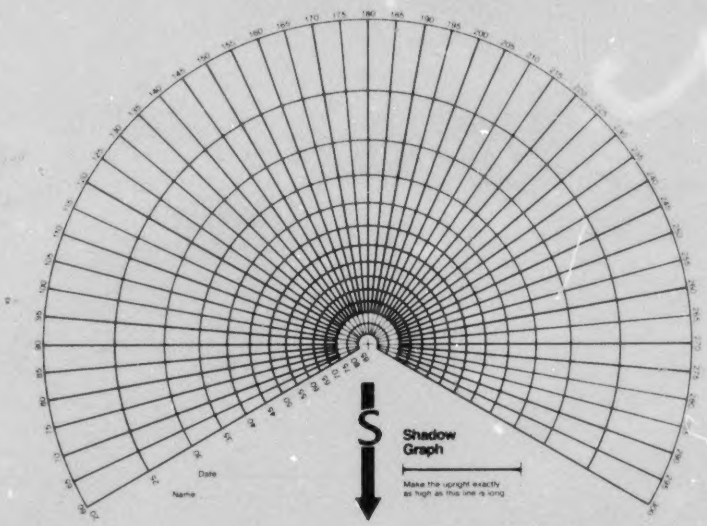
____

On the day you recorded the shadow, do you think the sun rose due east and set due west? ____________________ How could you measure the bearing of the rising or setting sun? ________________________________

6. Here is a picture of the board, graph, and straw as if we were looking down on it. If the sun were exactly southeast, what would its compass bearing be?

(Ignore magnetic variation.)______________________ degrees.

Draw the shadow the stick would make then. Draw in a sun due southwest.

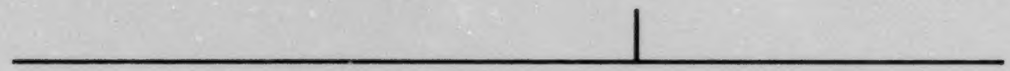


Can you find a set of numbers on the shadow graph you made that indicates compass bearings? Label this set of numbers **Bearings.**

Altitude

7. Here is a picture of the board and straw from the side. On your shadow graph, measure the line that tells how high the straw is to be. Now measure the distance between the circle marked "45 degrees" and the bottom of the place where the straw went through the paper. How do the two measurements compare?____________________

____



On the drawing, mark where the end of the shadow would be when it was on the line marked "45 degrees."

On the drawing, draw a line that represents a ray of sunlight that just barely goes over the top of the straw. (The ray beneath it hits the straw and is blocked; only the top of the straw makes a shadow.)

Suppose there is an ant with an astrolabe standing on your shadow graph. He is standing at the end of the shadow of the straw, exactly on the 45° line. He is trying to measure the altitude of the sun. Using your protractor, help him out by measuring the angle between the sun and the ground.

What is the sun's altitude then? __________________________________

One of the sets of numbers on your shadow graph indicates the altitude of the sun. The numbers name a set of lines. When the end of the straw's shadow is on the lines, the number of the line is the sun's altitude. Can you find this set of numbers? Label the set **Altitude.**

One of the sets of lines is curved and one is straight. One represents altitude; one represents bearings. Draw lines to match them up.

Bearing	parts of circles
Altitude	straight lines

From Shadow Graph to Sun Chart

Objectives

As a result of this lesson, students will be able to use a sun chart to find the position of the sun at any time of day of any day of the year.

Materials Needed

shadow graph with recording of one day's movement of the sun, from previous activity

blank graph paper with bearing and altitude scales identical to those on sun chart below, made from the master provided, one per student

worksheet **Creating a Sun Chart**

sun chart for your latitude, one per student

overhead transparency of sun chart optional, but very useful

Format of the Lesson

Discuss polar and rectangular coordinates (not in those words)

Compare form of sun chart with the new blank graph

Prepare table of points from shadow graph

Graph points onto new form

Review chart for the entire year

CONDUCTING THE LESSON

The difficulty of this lesson depends greatly on how much exposure to graphing the students have had in mathematics class. If students are uncertain of their graphing skills, it may be necessary to proceed very slowly, checking individual mastery after each step of the presentation.

Changing the Shadow Graph to Rectangular Coordinates

Discuss the shadow graph as graph paper. What are some ways it differs from ordinary graph paper? (ANS: Lines aren't evenly spaced. Some of the lines are parts of a circle.) Usually, graphs use straight lines evenly spaced. Let's see if we can transfer our data to that kind of a graph.

Pass out the blank rectangular graph paper. Ask students if it is similar in any way to the shadow graph form. Develop the observation that both forms have two axes marked with degrees. In both forms, one axis represents bearing and one represents altitude.

Each dot we made on the shadow graph represents three values: the altitude of the sun, the bearing of the sun, and, written next to the dot, the time of day. Those three numbers define the position of the sun at a particular time. On the chalkboard, make a table with three columns: time, bearing, altitude. Point out that we can take all the data we gathered using the shadow graph off the shadow graph form and present it in a completely new way, as a table. if the students have made individual shadow graphs, have them make tables from them. (You may choose to use the worksheet **Creating a Sun Chart** to guide students through this activity.) Once the tables are complete, put aside the shadow graph.

Now ask students to transfer the data from their tables to the new graph paper. The time of day can be entered just as we did on the shadow graph, that it, by writing it next to the dot that represents the altitude and bearing values. Finish the graph by drawing a smooth line through the dots.

Discuss a completed graph. Why are we justified in drawing a curve through the dots? After all, we didn't make measurements at all those points on the line. Ask students to give the altitude and bearing for some of the times between the dots, for which we don't have a measurement. Conclude that interpolation is justified.

Suppose we made a shadow graph on another day. Would we get the same line? Confirm that we would not, unless we happened to pick exactly the right day.

From One Day to a Year

With this introduction, students are now ready to receive a chart showing the movement of the sun over the year. Introduce it by saying that this is the chart they could make if they made a shadow graph on the 21st day of every month for a year. For the following discussion, it is very helpful to use an overhead transparency of the chart.

The heavy lines represent the sun's movement on certain days. Instead of dots, the times of day are represented by the thin lines. Ask students to give you the solar altitude for some times of day on the line for June 21, and then on the line for March 21.

Every heavy line except the innermost and outermost ones represent **two** days. Look at the vertical line in the center representing noon, when the sun is due south. On December 21 the sun is low in the sky. Then it starts getting higher and higher: January 21, February 21, etc. until on June 21 it is as high as it gets, and starts getting lower (July 21, August 21, etc.) until on December 21 it is back down low in the sky again.
So on February 21, for example, the sun will follow exactly the same path it did on October 21.

Ask if someone can guess how we would find the sun's position on a day for which there is no line on the chart. Practice interpolating between days of the year by giving students a date and asking what the altitude of the sun would be at noon on that day. Then reverse the process by putting a dot on the chart and asking students to tell you a time of day and day of the year when the sun would be in that position.

Creating a Sun Chart

By marking where the end of the straw's shadow was for a day, you made a record of the sun's movement.

But most people are not used to working with graph paper that has circles. People usually find graph paper with lines meeting at right angles is a lot more convenient. So in this exercise, you will transfer the record you made from the shadow graph to a regular rectangular graph.

To do this, you will need a piece of graph paper that your teacher will give you, your original shadow graph, and a sheet of plain ruled paper.

1. Look at the shadow graph. Each of the circles on it has a name. They are named in degrees. They show the altitude of the sun. Now look at the graph paper. The horizontal lines are named in degrees. We will use them to show the altitude of the sun. Find the line that represents the horizon, and trace over it.

2. Look at the shadow graph again. The lines radiating out from the center of the circles are named in degrees. They are the bearings. The line for South has the arrow we used to line the paper up with the compass. What bearing is due south? ________________ degrees.
Now look at the new sheet of graph paper. The vertical lines are named in degrees. The heavier vertical line in the center of the paper is named **180 degrees.** This represents a direction. What direction? ____________ All the other vertical lines also represent directions. Find southeast at 135 degrees. Find southwest at 225 degrees.

3. Now you are ready to move the information from one graph onto the other. Pick one of the dots you made on your shadow graph. A pair of numbers goes with this dot.

It indicates a sun altitude of ______________________________ degrees (taken from the circles).

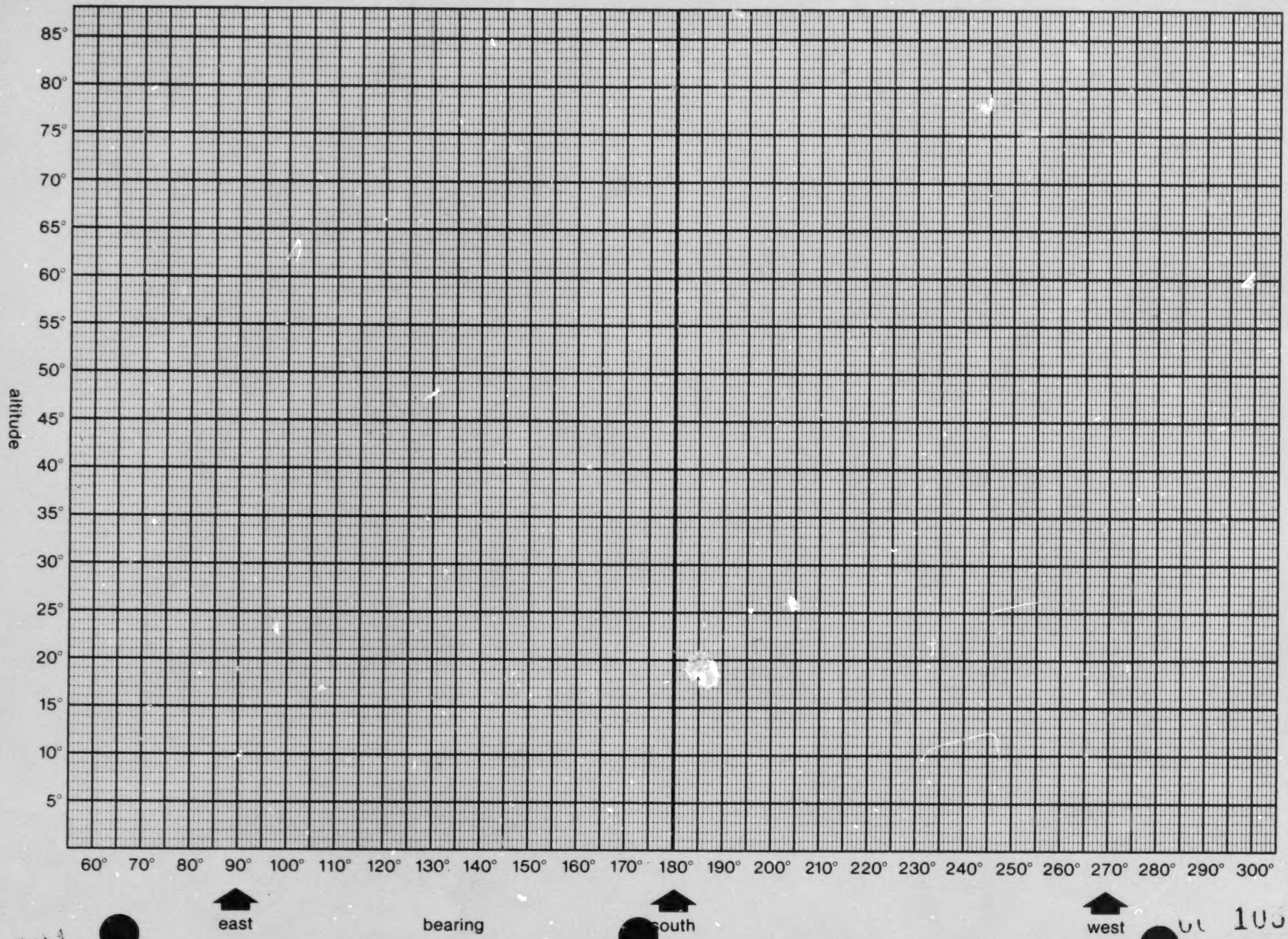
It indicates a sun bearing of ______________________________ degrees (taken from the radiating lines).

Make a dot on your new paper that indicates the same altitude and bearing. Now put up your hand and ask your teacher to check your work.

4. When your first new dot is approved, make a table on a sheet of paper. Make three columns in the table: time, altitude, and bearing. Pick a dot on your shadow graph. Put its time, altitude, and bearing on the table. Then make a dot on the new graph that will mean the same as the dot on the shadow graph did.

5. When you have finished transferring all the dots you originally made to the new graph, draw a smooth line through the new dots.

Congratulations! You have made a sun chart showing the sun's movement on a single day of the year. You could have been royal astronomer in ancient Egypt or Mexico!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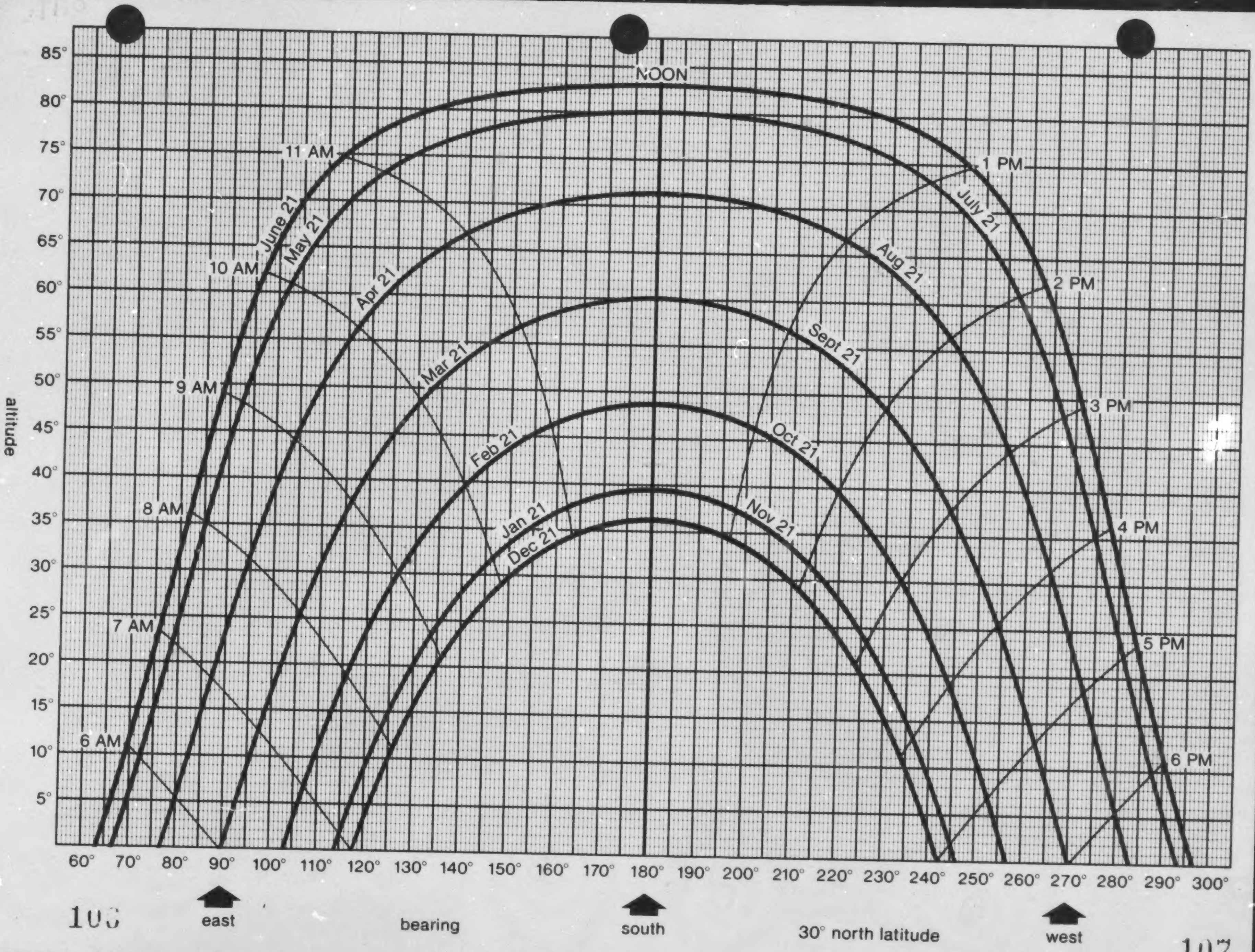
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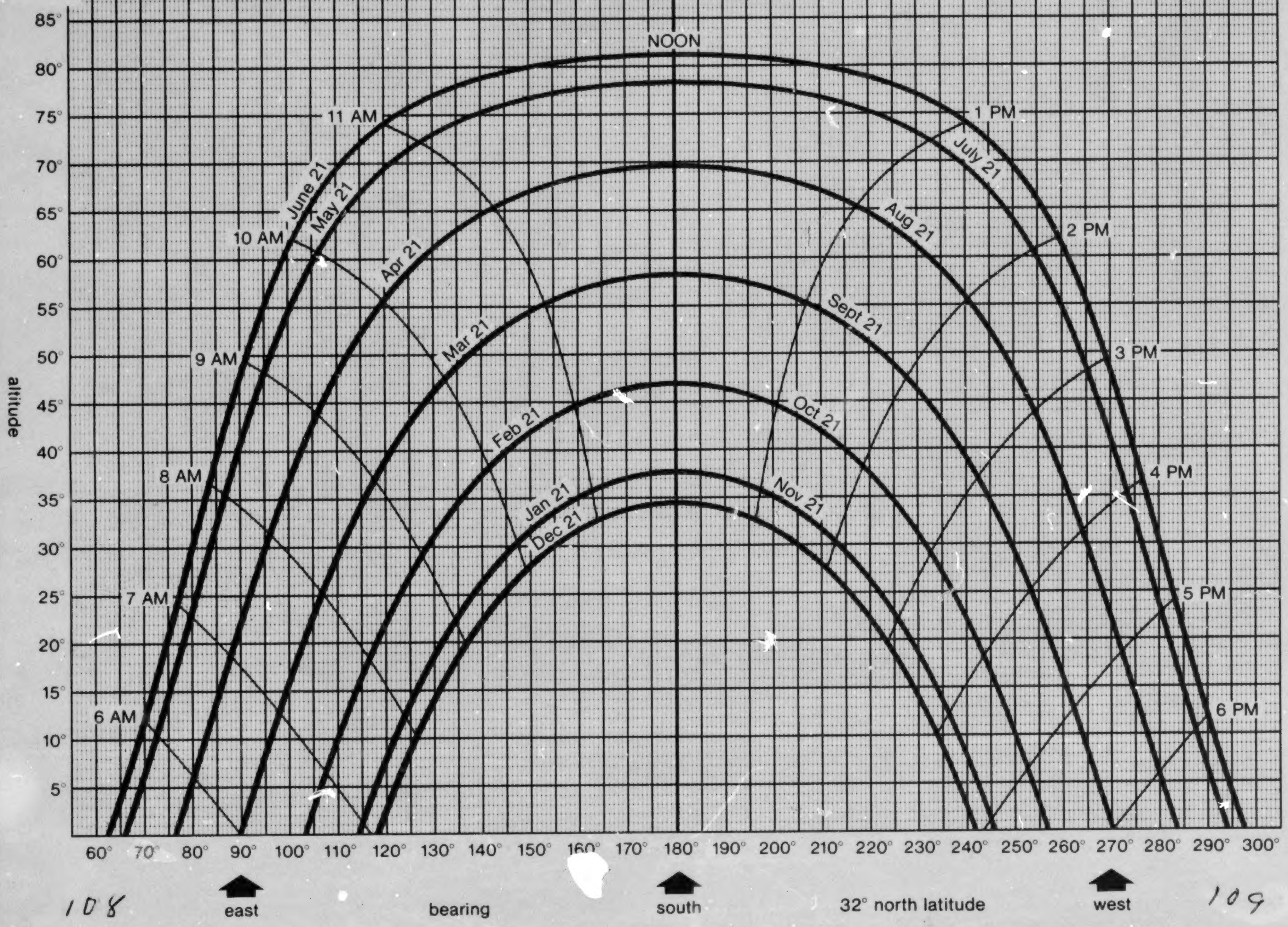
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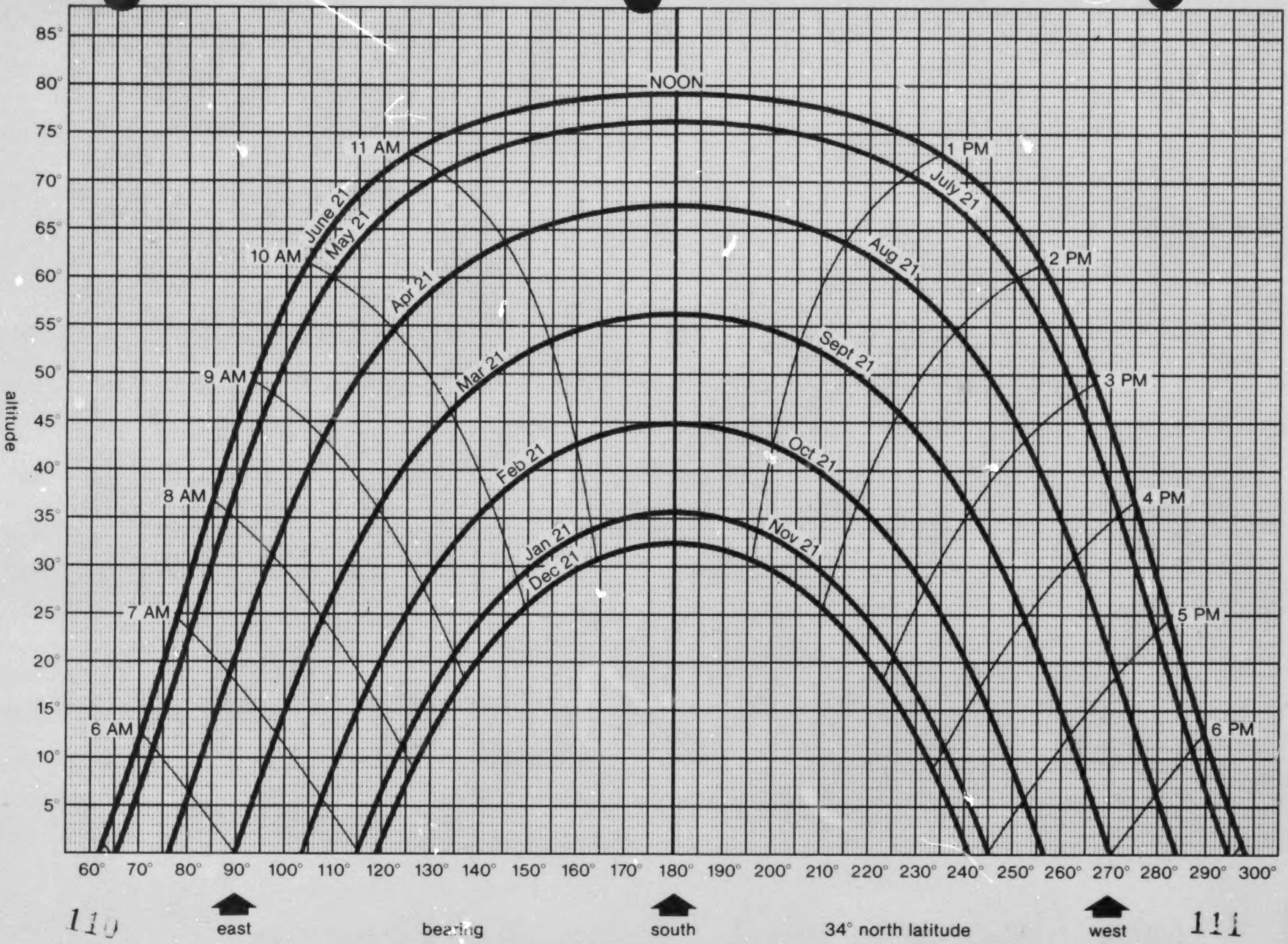
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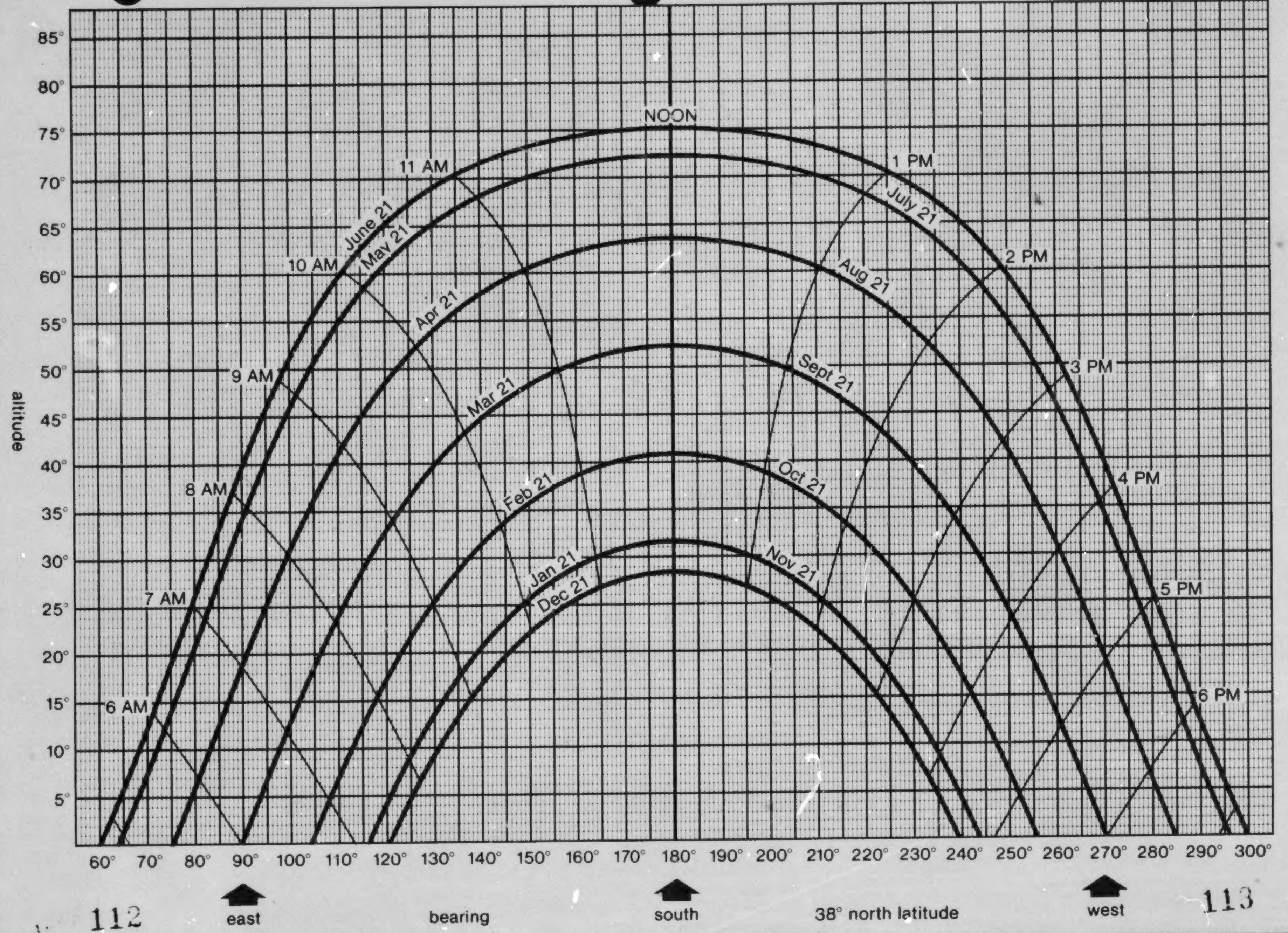
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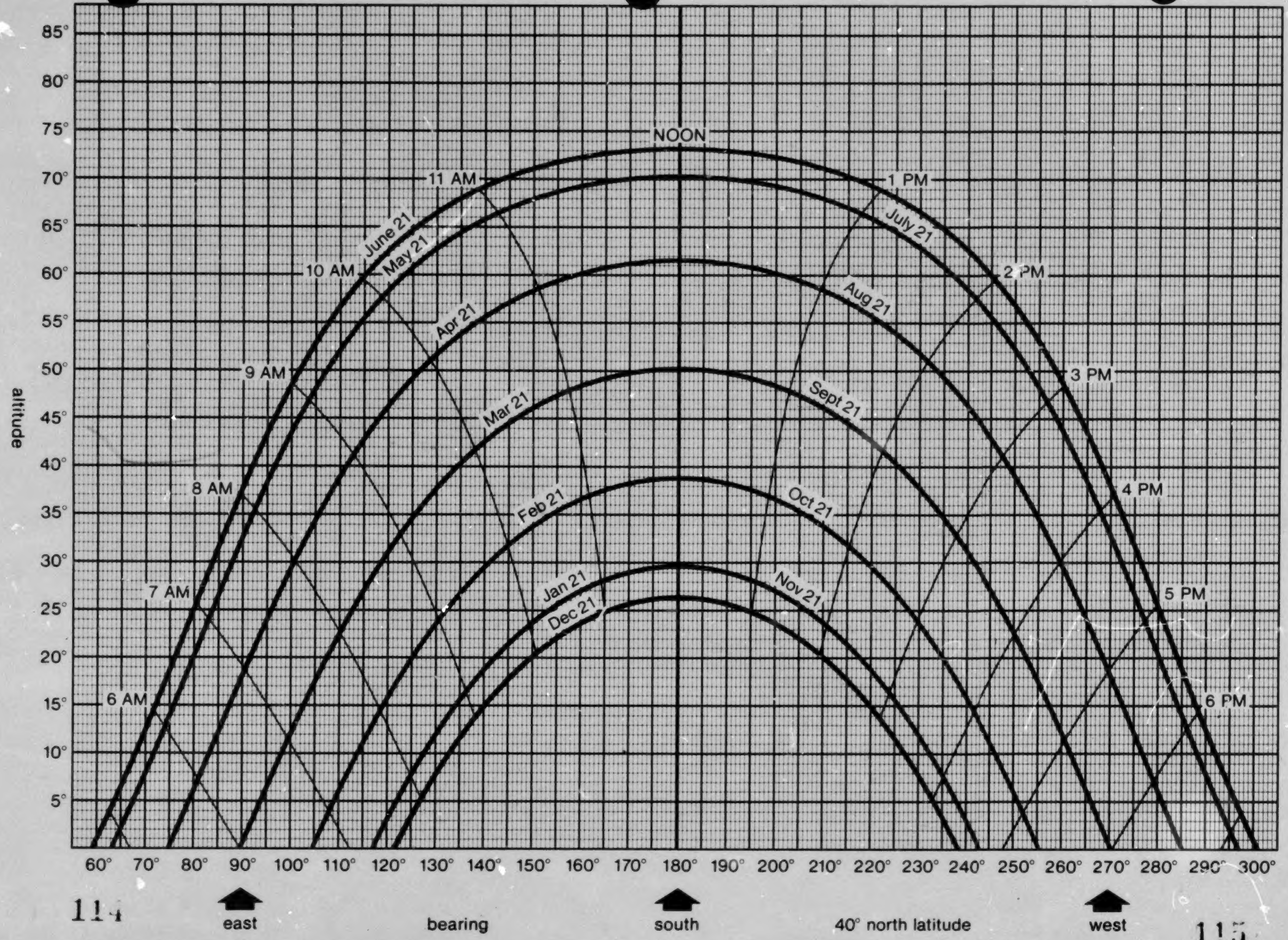
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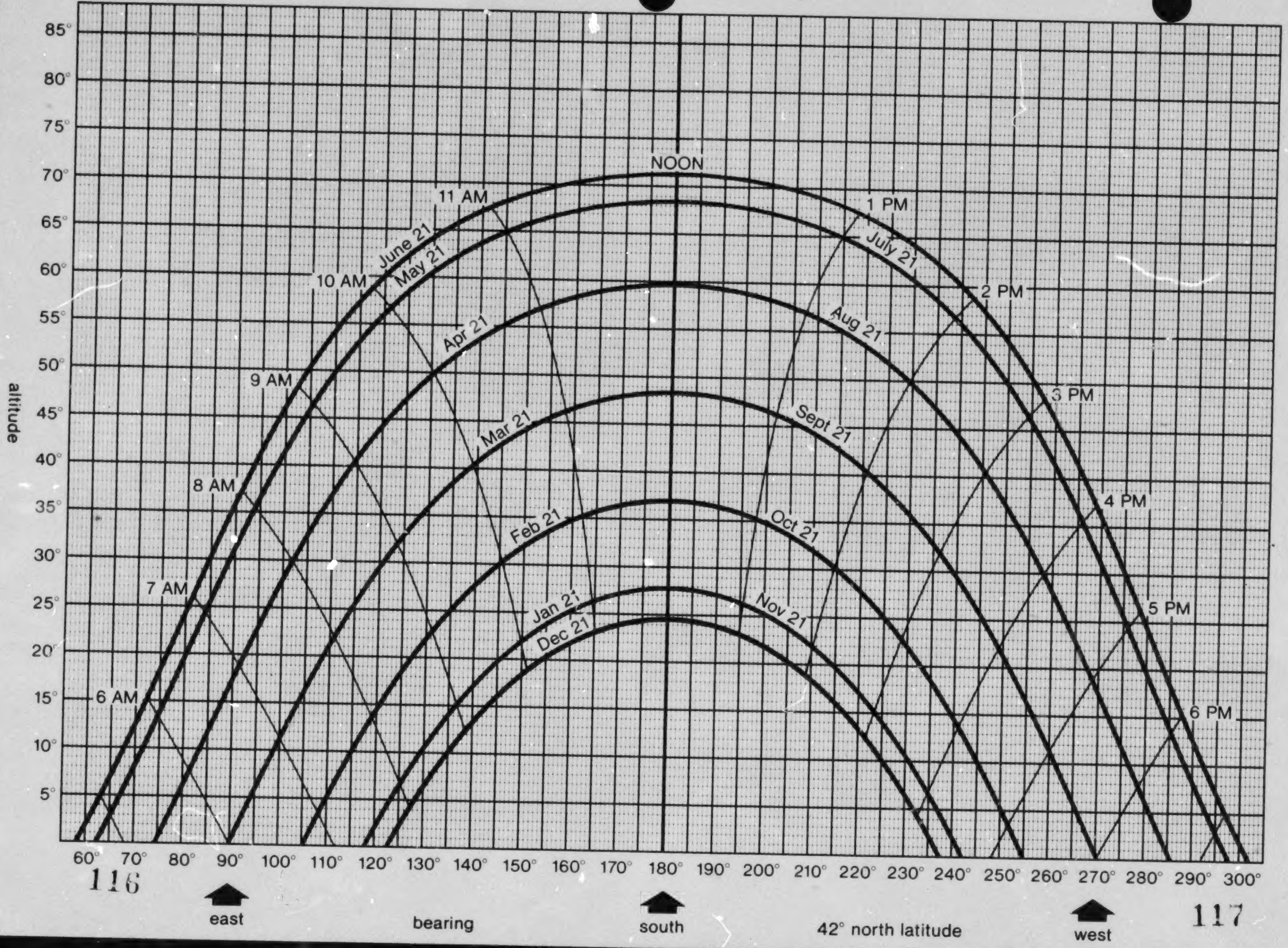
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Engineering an Overhang

To do this activity, you need a ruler, a protractor, a way of measuring feet, and the sun chart for your latitude.

Step One: Choose a room in your home that has some south-facing windows. Some homes, of course, don't have any such windows. If yours doesn't, choose such a room in your school.

Step Two: Here is some graph paper. Let one division on the graph equal one foot. Draw in a cross-section of the wall with the window in it. Your teacher will show you an example of how the finished drawing might look.

Step Three: At your home, what is the altitude of the sun at noon on June 21st? ______________ degrees

What is the altitude of the sun at noon on December 21st? ______________ degrees
(You can get this information from your sun chart)

Step Four: Now we want to draw the sunlight coming in the window on noon of June 21st. In Step Three, you found the angle this sunlight would make with the floor. Using a protractor and ruler, draw the ray of sunlight coming in the window that just missed the top of the window. Now draw the ray of sunlight that just missed the bottom of the window. Everything between these two lines would be in bright sunlight at noon, June 21st. Label the two lines June 21st.

Now do the same thing for December 21st, only this time make two dotted lines. Label these lines December 21st.

Step Five: When in the autumn does it start getting chilly where you live? When does your family start to use heaters or the furnace to warm your home? Pick a date. ______________________________

From your sun chart, what is the altitude of the sun at noon on that date? ______________ degrees

Step Six: Draw in a shade a carpenter could build onto the outside of your wall that would block as much sunlight as possible in the summer (to keep the room cool); but starting on the day you picked in Step Five, would let in all the sunlight all day long.

Going Another Step (optional): Suppose instead of an opaque awning or overhang you used mirrors, maybe even mirrors on the ground. Could you make the window seem bigger in winter and smaller in summer?

To all to whom these presents may come,

Greeting!

Know ye, that

____

having demonstrated an ability to predict the position of the sun in the heavens,
at any hour of any day of the year, and the times of sunrise and sunset,
is entitled to the exalted title of

Astronomer to the Pharaoh

together with all the honors and privileges appurtenant thereto.

In witness whereof, we have this day set our hands.

__________ Date

____________________ Chief of all the Scribes

____________________ Chief Astronomer

Reaching Higher Temperatures by Concentrating Sunlight

Note

This lesson can only be done on a sunny day. The class will be outside for most of the period.

Objectives

This lesson contributes to the students' understanding of the following concepts:

High temperatures can be obtained by focusing the sun's rays.

Sunlight can be focused by refraction through a lens, or by reflection.

Vocabulary

parabola

Materials Needed

magnifying glass the bigger the better.

Fresnel lens (optional) Edmund Scientific, catalog #70878, $6.

chalk

thermometers two.

liter measure

tin cans two screw-top, pint metal cans, both painted black on one side. These are the same cans used in the first lesson on solar collectors.

"3x5" card with the word "CONTROL" lettered on it.

mirrors preferably one per student. Plain mirror tiles work best, but they are expensive (a package of 6 costs $8), hard to find, and breakable. Alternatively, you can make mirrors by gluing aluminum foil (or much better, aluminized Mylar®), to pieces of heavy flat cardboard about a foot square. (A source of free Mylar is described on the next page.) To construct mirrors from foil or Mylar, you will also need cardboard, tape or glue, and scissors or a knife for cutting the cardboard.

Format of the Lesson

Make mirrors

Measure 500 milliliters of water into cans

Go outside

Demonstration: burn paper with magnifying glass

Reflect light onto target

Reflect light onto collector

Approximate parabola

A Source of Free Aluminized Mylar

The 3-M Company makes some high volume copiers that use aluminized Mylar. The copies are models number 235 (the VHS copier) and 238 (the VHS-R), and the Mylar is called catalog # 853 VHS Memory Tape. It comes as a roll about eight inches wide and hundreds of feet long. Apparently the Mylar winds back and forth in the machine like a typewriter ribbon; after several passes, it no longer meets 3-M's standard for smoothness and is replaced with a new roll. The "used" roll is thrown out—but it looks new to the naked eye and is very suitable for building solar reflectors—much better than aluminum foil. Randy West, Coordinator of the Environmental Resource Center of the San Juan (CA) Unified School District, who discovered this source, checked with 3-M and he says they say the backing of the foil is nontoxic.

The machines are designed for very high volume copying and are likely to be found in large hospitals, government agencies, very large corporations, and so forth. You can locate a user by calling the local 3-M Business Products office and explaining what you want and why. (Look in the white pages for their number.) They will then give you the names of a few owners of the machine. We suggest that, to avoid alienating both 3-M and the owners of their machines, the request be made by one person for an entire school district, and not for an individual school. A single copier provides more waste Mylar per year than could be used in a fairly large school district.

Be sure to have a class committee write a thank you letter to the organization donating the used Mylar—and to the local 3-M office that referred you to the organization.

CONDUCTING THE LESSON

Focusing on the Problem

Review with the class how we are able to get low-temperature heat (below the boiling point of water) from solar collectors (the lesson entitled **Collecting Heat from Sunlight**). Low-temperature heat is very important and useful. Ask the class to name some of the things we need low-temperature heat for in our daily lives. (ANS: For heating our houses, warming hot water for washing, heating swimming pools, etc.)

Low-temperature heat is also needed for many industrial processes, like drying fruit. But for many other uses we need high-temperature heat. Can we use sunshine to get high temperatures? That is the problem we'll investigate today.

Making the Mirrors

You may want to make the mirrors before today's lesson—perhaps on a cloudy day. If you have not yet made the mirrors, do so now. Show the students a completed mirror and distribute materials (Mylar or aluminum foil, cardboard, transparent tape).

Ask the students to cut out pieces of corrugated cardboard. The exact dimensions are not important, but the typical area should be about one square foot. Cover the piece of cardboard with an unwrinkled piece of foil or Mylar, taping one edge to the cardboard, stretching the foil or Mylar tight, and then taping the opposite edge. Finally, tape the other two edges.

The whole job will probably take about five minutes.

Take the class outside. Take with you:

- magnifying glasses or Fresnel lens
- sheets of paper
- mirrors
- a piece of chalk
- two cans, each with one black side
- two thermometers
- water
- a measuring cup
- a watch
- "3x5" card labeled "CONTROL"

Concentrating Light with a Lens

Perform the following demonstration for the students.

Lay the lens on the paper. You are going to demonstrate that the lens achieves its higher temperatures by concentrating the light passing through it into a smaller area.

"How large an area of the paper is the light going through the lens hitting?" (ANS: An area about as big as the lens.)

Slowly raise the lens. Point out that the lens is bending the light rays. The bright spot on the paper is made by light that has passed through the lens.

"What happens to the size of the bright spot as we raise the lens?" (ANS: It gets smaller.)

"So, we are concentrating the light energy going through the lens into a smaller and smaller area. How will this affect how high a temperature we can reach?" (ANS: The point onto which we are concentrating the light will reach a higher temperature than it would if we just exposed it to unconcentrated sunlight.)

At this point, the paper should start to burn, confirming the guess.

So one way of getting higher temperatures from sunlight is to change the direction of the light rays so that many of them fall on a small area.

If possible, let students play with the lens and paper themselves.

Making Two Suns, Three Suns, More

Have the class stand in the sun, in a place where they can face a brick or concrete building or masonry wall that is in shadow. On the wall, at about head height, chalk a circular target about 25 centimeters in diameter. (Rain will wash it off!)

Give one student a mirror and ask her to use her mirror to reflect sunlight onto the target. Compliment her when she hits the target and ask where the bright spot is coming from. (ANS: It comes from the sun. It comes from the light hitting the mirror.)

Now, while the first student continues to use her mirror to reflect sunlight onto the spot on the wall, give a second student a mirror and ask him to reflect light onto the target, too. When he succeeds, ask the class, how much more light is reaching the target than before? (ANS: Twice as much, since the sunlight falling on two mirrors is now reaching the target.)

Then give out all available mirrors and ask the students to try to hit the target simultaneously. Observe how bright the spot is. For safety's sake, ask the students to put down all the mirrors on the ground, and then invite students to feel the spot on the wall. While they are doing this, you might discuss whether all the light reaching the mirrors got to the target. (ANS: No, the mirrors aren't perfect reflectors. They absorb some light. Some light bounces off in the wrong direction.)

A Temporary Concentrating Collector

Tell the class we will now do an experiment. We know that our tin-can collector can only absorb sunlight that falls on it, so the amount of sunlight absorbed depends on the size of the collector. Suppose we use the same can but collect sunlight over a much larger area: namely, from the surfaces of all our mirrors. We will try to put all that sunlight onto the collector. Will the collector heat up faster?

To do an experiment like this you need a control. Our control is an identical can on which we will NOT reflect sunlight, but which we will place where direct sunlight falls on it just as it does on our target can. The control will show us how much heat the target can would have collected just from sunlight falling directly upon it.

Place the two tins full of water on the ground, at least five feet apart (to keep the control from being hit by mis-aimed reflections), and arranged so that the sides of the cans that aren't black squarely face the sun. Designate one can the control by propping the 3"x5" card against it. Remind students which can is the target and ask them to reflect light on that can only, not on the control can, which would interfere with the experiment.

Unscrew the caps from the cans.

Assign two students to measure the beginning temperature of the water in each of the cans.

Emphasize to the students that we are going to try to concentrate sunlight and that sunlight is powerful stuff. Goofing around cannot be permitted.

We will try to heat the water in the tin can by aiming the reflections from our mirrors at it. But we will only do it on signal. When the signal to stop is given, we will put the mirrors gently down on the ground. Let's practice.

Place the mirrors on the ground in a semicircle around the can. One by one, ask each student to pick up his or her mirror and practice hitting the can. When they can hit the can, have them put the mirror back down.

Empty the can and pour 500 mL of water into it. Measure the temperature of the water in each of the two cans and record the measurements. The water in the two cans should be the same temperature.

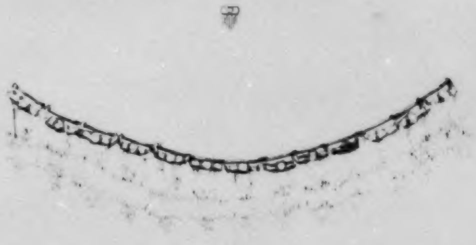
Check that no students are loitering near the target can. Note the time and tell the students, "Go." After two minutes, have them put the mirrors down. Have students measure the temperature of the water in each of the cans and announce their findings to the class.

Approximating a Parabola

Next, give the students an intuitive idea of the shape a mirror would have to have if it was able to reflect all the sunlight falling on it to one point (such as the can.)

Ask the students whether, when they were all reflecting light onto the can, their mirrors all faced the same direction. (ANS: No.) A big flat mirror does not reflect all the light falling on it to a point. If we had one big mirror, what shape would it have to be so that all the light hitting the mirror was reflected to the can?

Place a target can on the ground in full sunlight, with the black side of the can facing away from the sun, and the can's shadow at right angles to its surface. (See drawing below).



Ask a student with a mirror to stand directly in line with the shadow, but about 5 meters back, and ask that student to reflect light onto the can. Then ask two other students with mirrors to stand next to the first student, one on the left and one on the right, holding their mirrors so that one edge touches the mirror held by the first student, and reflect light onto the can. Demonstrate what you mean. Continue adding more students on the left and right, always checking that the mirrors touch.

Point out that they have made a curved mirror. Take a piece of chalk and trace along the toes of the students' shoes. Have them stand back and look at the curve. This is a kind of curve called a parabola.

Collect the materials and return to the classroom.

Projects for Independent Investigation

1. Find the story about how the Greek scientist Archimedes destroyed the Roman ships attacking his city. Tell the story to the class.

Do historians believe this story is accurate? Do you think it would be possible to do what Archimedes is said to have done?

2. Examine the reflector in a flashlight. What shape does it have?

Notes

Solar Rotisserie

Building a Solar Rotisserie

Note: The collector described here produces high temperatures at the focus point and must be treated with respect. Careless handling in direct sunlight can lead to injury. Never leave it unattended out-of-doors. Warn students not to test the cooker by putting their hands in front of it. These cautions should be given prior to building the cooker and repeated before using it.

Objectives

This lesson contributes to students' understanding of the following concepts:

Sunlight can be used to obtain high temperatures.

The direction of light can be changed by reflection.

An understanding of the mathematical relationships between measurements may be used to estimate the required size and feasibility of devices.

Metrics

The chalkboard calculations in this lesson are not done in SI units. This was done deliberately, because a major purpose of the lesson is to encourage students to think about what would be involved in using sunlight as a direct energy source for familiar daily activities. Talking about oven thermostats marked in degrees Celsius and hot dogs bought by the kilo conveys an air of unreality that conflicts with this objective.

Teachers who do not agree can easily convert the temperatures, the hot dog weight and length, and the rate of insolation to metric units.

Format of the Lesson

Discuss people's need for temperatures higher than that of boiling water

Elicit idea of concentrating sunlight to reach high temperatures

Estimate the size of the aperture needed to collect the amount of sunlight required to cook a hotdog

Construct parabola

Assemble materials

Take cooker outside and cook something

Prerequisites

To follow the discussion in this lesson, students need to be familiar with Btu's (or, if the lesson is converted to metric, with calories), and they need to have a rough idea of how much heat can be collected in their latitude from sunlight falling on a surface for one hour. These topics are taught in the heat measurement activities in Unit One, and the solar collector lesson at the beginning of this unit, respectively.

Materials Needed

cardboard big sheets from appliance cartons (at least two) to form the sides of the rotisserie. A long sheet, 27" x 55" (75 cm by 150 cm) of thinner corrugated cardboard to form the reflector.

aluminized Mylar (chrome Mylar) enough to cover your reflector. See the note in the previous lesson on a free source of Mylar. If you have to buy it, 55" wide Mylar sells for about $3.50 a yard. Aluminum foil is a poor substitute; a much larger collecting surface is needed to produce the same amount of heat.

If a local source is not available, aluminized Mylar can be mail-ordered from:

Plastic Mart
2101 Pico Boulevard
Santa Monica, CA 90405
(213) 451-1701

paper or cardboard a piece big enough to construct a pattern for your parabolic reflector, about 18" x 24" (50 cm by 80 cm.)

shipping tape such as Scotch catalog #395.

iron rod 36" x 3/16", to make the spit (about 80^{0} at a hardware store). Do not get "drill rod"; it's hardened and won't bend. Or you can use a coat hanger from which *all* paint has been removed.

wood one-by-two, about 14 running feet.

staple gun (optional).

staples either to fit the above staple-gun or to hammer in, 1/2" or 5/8" legs.

saw the kind that has replaceable blades that fit a knife handle. (See the article on cardboard carpentry in the introduction to the manual.)

hammer

nails 6d common box nails, a few dozen.

drill with 1/2" bit, hand or electric.

framing square or drafting triangle. Borrow from the school shop.

meterstick or yardstick.

adhesive such as Scotch Spra**mount** Artist's Adhesive (DO NOT use Scotch Spra**ment** Arts and Crafts Adhesive.)

Why This Design?

The solar cooker whose construction is described in this lesson is big: 27" wide (half the width of rolls of aluminized Mylar, with margin for error); and 48" high. You may be familiar with other designs; we have used this one because:

This cooker can be built from scratch in a few class periods, and no special skills in the use of tools are required. Power tools are not needed. To achieve this, durability was sacrificed: the cooker is cardboard. If you need durability, follow the same design but substitute 3/4" plywood for the sides and 1/8" hardboard (such as Masonite®) for the reflector. (In that case, also consider making the reflector the full 8' length of the Masonite.)

The cooker can be very cheap if you can scrounge the wood and Mylar; as little as $1 (for shipping tape).

The cooker *cooks*. As discussed in the lesson, the aperture of a collector determines how much heat the collector can provide. Most published designs are for much smaller hot dog cookers. Smaller designs allow each student to make his or her own, but result in cookers that will not heat the food in a reasonable length of time. A design with a 1 square foot aperture can take almost an hour to make a hot dog lukewarm. This is very unfortunate, for a number of reasons. If you plan to take a class out to wait on the playground for 45 minutes while their hot dogs warm up, you'd better have some awfully interesting interim activities planned—as well as a good way of fending off neighborhood dogs. Perhaps even more important is the impression the cooker's performance makes on the students. We think such an experience reinforces the commonly held misconception that solar energy may be fun but is too weak to be practical. People would have the same idea about natural gas if we cooked hot dogs over pilot lights. Of course, we don't; we use adequately sized burners. Similarly, this cooker is sized to do the job using the energy source available to it. Students are not sophisticated enough to realize that the inadequate performance of smaller cookers is not inherent in the energy source but in the poor engineering of the cooker.

CONDUCTING THE LESSON

The first part of this lesson is a chalkboard talk in which you "walk" the students through an analysis of how big a solar hot dog cooker would have to be, using simple calculations. As a way of presenting a sequence of questions through which this lesson proceeds, sample questions are provided. Of course, you will want to use your own wording and adapt the presentation to your class. In any case, it's essential to work through the lesson once yourself, including the calculations, before presenting it to a class.

The Basic Idea: Concentrating Sunlight

Review the previous lesson. The water in the collector can onto which we reflected light became much hotter than the water in the control can that was just sitting in the sun.

The Need for High Temperatures in the Home

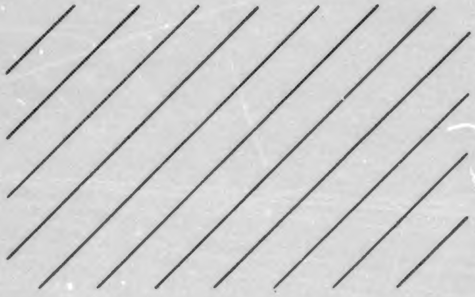
"We know that we can use sunlight to get temperatures as hot as those of hot water used for bathing and washing dishes. At home, do we ever need temperatures higher than the temperature of this hot water? What for?" (ANS: In the home, high temperatures are needed for cooking, for ironing, etc.)

"What temperature do we need to boil water?" (ANS: 100°C, or 212°F.)

"What is the highest temperature marked on an oven control or the dial of an electric frying pan?" (ANS: Usually 500° or 550° Fahrenheit; few dials are marked in degrees Celsius.)

"Can we use the energy of sunlight to reach the range of temperatures needed in cooking? Let's see."

Draw slanting parallel lines on the chalkboard, as shown in the figure. As the discussion proceeds, you will add to this drawing.



"Here are some of the sun's rays coming in.

"How many of you have ever eaten a hot dog? Do you like them? How many have ever eaten a cold hot dog? Are hot dogs better hot or cold?" (ANS: Hot!)

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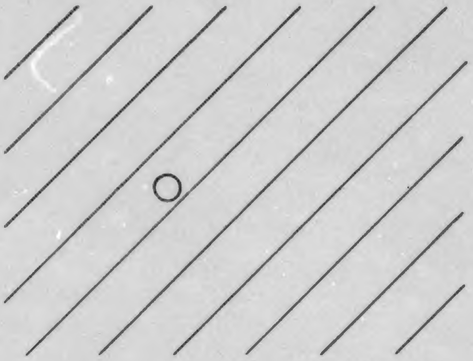
"So heating hot dogs is a useful thing to do. Let's see if we can use sunlight to heat the hot dog."

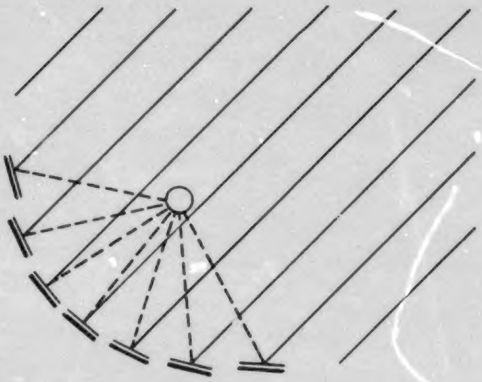
Draw a small circle in the middle of the rays to represent the hot dog.



"Here is the hot dog. It's a circle because we're looking at the hot dog end on. How can we use this light to make this hot dog hot?"

If no one responds, prompt by asking, "Suppose we had some mirrors. Where could you put them to reflect light onto the hot dog?"

Invite students to come to the board and draw in mirrors that would reflect the rays you have drawn onto the hot dog. The final drawing should look something like the drawing below.



To Estimate How Big the Cooker Must Be, Estimate the Amount of Heat Needed

Explain that one of the first things an engineer does in building a new device is make a rough estimate of how big the parts will have to be to do the job. To find out how big our cooker should be, we have to estimate how much energy we would need to cook something. Then we could make a rough guess about how much sunlight we would need to do that.

Estimating Quantity of Heat Required

"Let's say hot dogs are as difficult to heat as water." (Actually, they aren't. More heat has to be supplied to raise the temperature of a mass of water 1 degree than to raise the temperature of an equal mass of just about anything else 1 degree. Water has what physicists call a very high *specific heat.* But if the class has not previously studied specific heat, this is obviously not the place to introduce the topic.)

"How much heat does it take to raise the temperature of 1 pound of water 1 degree Fahrenheit?" (ANS: 1 Btu; that is the definition of a Btu.) If we assume the hot dog is as difficult to heat as water, how much heat is needed to raise the temperature of 1 pound of hot dogs 1 degree Fahrenheit? (ANS: 1 Btu.)

"You get 10 hot dogs in a pound. So how much does 1 hot dog weigh? (ANS: 1/10 of a pound.)

130

"Hot dogs come from the refrigerator at about 42° Fahrenheit. What is the temperature of a cooked hot dog?" (ANS: The temperature of boiling water, about 212°F.) "By how many degrees is the temperature of the hot dogs raised?" (ANS: 170°. The boiling point, 212°, minus 42°, the temperature in the refrigerator.)

"Now we're ready to figure out how many Btu we need to supply to warm up 1 hot dog. How many Btu would be needed to raise the temperature of 1 pound of water 170 degrees?" (ANS: 170 Btu, because a Btu is defined as the quantity of heat needed to raise the temperature of 1 pound of water degree Fahrenheit.)

"We're assuming that hot dogs are exactly as difficult to heat as water, so it would take 170 Btu to warm 1 pound of hot dogs. Since there are 10 hot dogs to a pound, how many Btu would it take to warm 1 hot dog?" (ANS: 17 Btu—170 divided by 10.)

Estimating Rate

"How long are we willing to wait for the hot dog to cook? An hour? Half an hour?" Lead the students to accept 5 minutes as a reasonable length of time; it simplifies calculations.

"Therefore, we need to transfer heat at the rate of 17 Btu every 5 minutes. A rate of 17 Btu in 5 minutes would be the same as how many Btu in 60 minutes? (ANS: 204 Btu per hour. There are 12 five-minute periods in an hour; 17 x 12 = 204.) Tell the class that for the kind of rough and ready estimating we are doing, 4 Btu is not meaningful. Round the "204" off to an even 200.

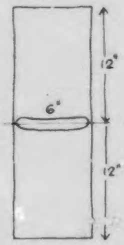
"So to cook the hot dog in 5 minutes, our cooker has to be able to supply heat at the rate of 200 Btu an hour. How much sunlight do we need to be able to do that?"

Estimating the Size of the Aperture

If the students have previously measured the rate of insolation, you can use their figures, rounded off. If they haven't, you can point out that an average sort of figure for the United States, for noon on a sunny day, is about 200 Btu per square foot per hour, though sometimes it can be twice as much—or half as much—as this. "We know that on a sunny day we can get about 200 Btu per square foot in 1 hour."

Now make a second drawing (without erasing the first) in which we are looking at the hot dog from the direction of the sun. Thus we are looking head on at the collection area.

"So here's a hot dog, 6" long. Here's the area where there is a mirror. Sunlight falling on the mirror will be reflected onto the hot dog.

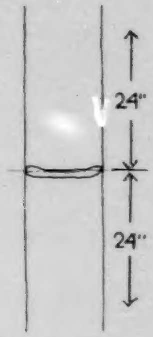


"To get 200 Btu in 1 hour we need a collecting area of 1 square foot. How can we get a collector area that big?" (ANS: 1 square foot (12" by 12") is 144 square inches. A rectangle 6" wide with an area of 144 square inches must be 24" long. So if the aperture extended 12 " on either side of the hot dog it would capture 1 square foot of sunlight.)

"How good an absorber is the hot dog? Is it black? Is it a dark color? No, kind of pink. Probably it is not a very good absorber of sunlight. (How could you find out experimentally how good an absorber a hot dog is?) If the hot dog only absorbs 50% of the light, how will that affect the area we need?

(ANS: We'll have to double the area of the aperture.)

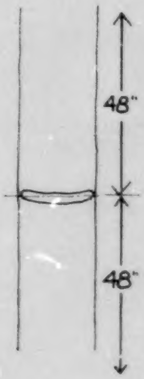
"What will the size of our aperture be if we double the area?" (ANS: It will extend 24" on each side of the hot dog.)



"How good a reflector is the Mylar (or foil)? Does all the light that hits the Mylar get to the focus point?" (ANS: No. Some of it is scattered in other directions.)

"Let's suppose that 50% does. How will that change how big a collecting area we will need to get 200 Btu in one hour?" (ANS: We will have to double it.)

Doubling the collecting area again will make the aperture extend 48" on each side of the hot dog.



Reviewing Assumptions

"Let's go back now. At various points we made some guesses about information we needed. We didn't have exact data, we made an educated guess. We assumed some things were true. How accurate our result is depends on how accurate our assumptions were. Can anyone tell me one of our assumptions?"

Here is a list of the assumptions that may be elicited.

("What is needed to cook a hot dog?")
1. A hot dog heats like water, i.e., has the same specific heat.
2. Cooking a hot dog involves raising the temperature from refrigerator cold to boiling-water hot.

("What did we assume about the size of the hot dog?")
3. A hot dog weighs 1/10 pound and is 6" long.

("Did we make any assumptions about the energy available as sunlight?")
4. Insolation = 200 Btu/square foot/hour

5. A hot dog absorbs 50% of the radiant energy falling on it.

6. The reflector reflects 50% of the light to the focus point.

Notice that most of the assumptions are conservative. Hot dogs are not as difficult to heat as water, many reflecting materials reflect more than 50% of the light, and, on a sunny day, insolation rates can be as high as 400 Btu per hour. Real engineers try to be conservative in their assumptions, too, because they feel it is better to have something that costs more than it needed to (i.e., is too big or strong) than to make something that doesn't work at all. (What problems might this create for the efficient use of resources? Why might the first-of-a-kind be less efficient than a later model?)

Building a Solar Rotisserie

Suppose we now want to build the cooker we've designed. Although we *could* build one 8' long, we would have to use a fairly strong material, like an 8' piece of plywood. Since we want to test the idea first, suppose we first use a cheap but weaker material, like cardboard. With cardboard, we can build a cooker with an aperture 4' long. What will that do to our estimated cooking time? (ANS: Double it, from 5 minutes to 10 minutes, since the cooker will be half the height of the one we figured we'd need to cook the hot dog in 5 minutes.)

Explain to the students that we will first develop the curve for the reflector, and then break into teams to make different parts of the cooker. Finally, the whole class will assemble the cooker and try it out together.

Constructing a Parabola Pattern

The reflector in the cooker must be curved so that all the light falling on it will be reflected onto the hot dog. Such a curve is called a parabola. First we will make a paper pattern of half of a parabola, and then trace the pattern onto the cardboard sides.

To save time or suit the abilities of your students, you may wish to draw the parabola pattern outside of class yourself, or have it drawn by a group of selected students. If you wish to do it as a class activity, directions for four different ways of drawing a parabola are provided. You may choose to have everyone use the same method, or you may wish to assign teams to different methods. The first method requires taking square roots (we suggest a calculator be used). Method two is the easiest. The fourth method requires the ability to bisect a line and is the most difficult.

Advanced students who have had some geometry may be interested in exploring the hidden similarities in these different methods.

Building the Pieces of the Cooker

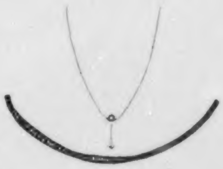
After constructing the parabola, divide the class into four groups to perform the construction activities. Note that the groups' assignments are not equally difficult.

Assembling the Reflector

Once the various pieces have been made, the next step is best done by the teacher rather than the students because it is most easily accomplished with an aerosol glue, the misuse of which can be dangerous. Many glues won't hold Mylar. Scotch Spramount will and is forgiving of mistakes. It is repositionable: if the Mylar hits wrong or becomes wrinkled, you can pull it up and try again.

Out of doors, in as windfree a place as possible, spray one side of the cardboard sheet. Be sure the excess spray doesn't drift onto the Mylar, and that no one is standing where they could breathe it.

Hold the Mylar so it drapes down in a U-shape with the centerline on the inside at the bottom of the U. (This takes three people: one holding each end, and one handling the middle.) It is helpful to have a dowel inside the Mylar, along the centerline, as a weight. Bend the corrugated cardboard until it is about the same curve as the sides. Slowly lower the Mylar, keeping the centerline lined up with the centerline marked on the cardboard. When it touches, slowly smooth out the Mylar, starting from the middle.



Assembling the Cooker

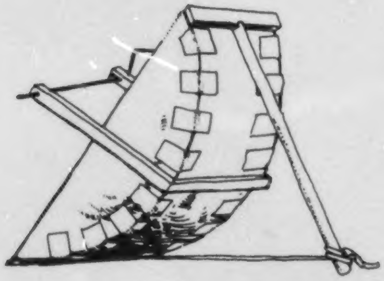
Take one of the two sides and rest it on the edge of the reflector, at right angles to it, so that its centerline and the centerline on the back of the reflector line up. Run a piece of packaging tape about a foot long down the side and onto the back of the reflector, making an L. Cut another foot of tape and do the same thing over again, farther up the side. The reflector will bend to conform to the curve of the side. Continue in the same way until both sides have been taped in place.

Using 1/2" or 5/8" staples, staple a 27" one-by-two across the bottom of the reflector and another across the top. A staple gun is very handy for this. Use lots of staples to spread the load evenly over the cardboard.

Now attach the supports for the spit by stapling them to the cardboard. Place them by lining up the middle of the one-by-two with the centerlines marked on the sides.

Take the one-by-two that is 26¼" long and place it on edge inside the reflector, between the two spit supports. Staple the reflector to it. (You need a block or something to put inside the reflector to support the piece of wood while this is being done.) Then nail through the spit supports into the wood inside.

To make the support for the solar cooker, fasten a string around the one by two on the bottom of the cooker (punch a hole through the reflector). Tape the 44" piece of one-by-two to the top one-by-two, making a hinge; tie the string through and around the notches on the bottom using a bowknot, so that the reflector is aimed at the sun.



Cooking Something

Take the cooker outside on a sunny day and cook something, cautioning the students beforehand that this is a surprisingly powerful device.

Never leave the cooker outside unattended. One school building was set on fire by sunlight focused on it by a cooker left leaning against the building. (Fortunately, it did not burn down.)

The standard item cooked on these devices is the humble hot dog, or "tube steak." It works fine. But some people can't eat hot dogs, and others question their nutritional value. So here are some alternatives that at least some students like.

Solar Bread Mix a stiff biscuit dough. (You can use Bisquick and water.) Roll into balls and put on spit. Turn constantly till brown. (You may need to turn the balls with a stick if the spit itself it too slippery.)

Baked Apple Hawaiian Cut large apples into quarters, remove core. Let soak in bowl of juice from canned pineapple, stirring occasionally. Shake off excess moisture. Roast until soft. Push off onto plate.

Marshmallows Sugary, but fun.

Brown and Serve Rolls Expensive but easy. Just spit and bake.

Practical Applications

Point out to the students that many of the commercially manufactured solar collectors designed to reach high temperatures use the same design (a parabolic trough) as the hot dog cooker, except that the hot dog is replaced with a double-walled glass tube. The outer part is evacuated (like a Thermos® bottle), to prevent heat loss by conduction, and the inner part contains a circulating fluid. Such collectors are used, for example, to power air conditioners. Articles with illustrations of such systems appear from time to time in magazines like *Popular Science*. You may wish to use these to make a bulletin board display.

Projects for Independent Investigation

1. Build a solar oven and bake something. Directions for such ovens can be found in the following books and others you may be able to find in your library.

John Barling's Solar Fun Book, 18 Projects for the Weekend Builder, by John Barling (Brick House Publishing, Andover, MA. 1979.) Page 25. A fancy oven.

Solar Science Projects for a Cleaner Environment, by D.S. Halacy Jr. (Scholastic Book Services. 1974). Page 51. [The same material is reprinted in the *Mother Earth News Handbook of Homemade Power* (Bantam Books, New York, NY. 1974) Page 262.]

Solar Energy (activity 10) and *Solar Energy II* (activity 12) from the Oak Ridge Associated Universities.

2. Build a solar food dehydrator.

3. Report on "Solar Power Towers" to the class. Use a chalkboard drawing to explain how they work.

4. Using a photographer's light meter, invent a way of measuring the percentage of incoming light that bounces off a surface at the angle of reflection. Make a measurement on a silvered glass mirror, a piece of aluminum foil, a piece of aluminized Mylar, and a piece of white paper.

5. Invent a way to measure the specific heat of hot dogs.

Courtesy Solar Kinetics, Inc.

Team One: Constructing a Parabola by Graphing

A parabola can be constructed by graphing a parabolic equation.

The formula for a parabola, placing the origin (0,0) of the graph at the "bottom" of the parabola, is

$$y2 = 4Fx$$

where F is the focal distance. For cookers as large as the one you will build, a focal distance of 18" is about right. So, let F = 18.

To do this, you will need:

☐ sheet of posterboard about 18" by 24". Be sure it has at least one square (90^{0}) corner. If posterboard isn't available, tape together smaller sheets of plain white paper to make a sheet this size. You do not need graph paper to graph the curve.

☐ calculator that can find square roots

☐ drafting triangle or carpenter's square

☐ ruler

Procedure

Step One: Make a table of pairs of points that lie on the parabola. Use only the positive values of x and y. If your teacher approves, use a calculator with a square root function to do this.

The more points plotted the more accurate the curve will be and the better the cooker will work. It is especially helpful to have fractional values of x between 0 and 2, like x = 1/2. Here is an example:

$$\begin{aligned} \text{if } x &= 2 \text{ then} \\ y2 &= 4(18)(2) \\ y2 &= 144 \\ y &= 12 \end{aligned}$$

x	y
0	0
2	12

Step Two: The edges of the paper will be the axes of the graph. (That is why we are using only positive values.) The 18" edge will be the x-axis and the 24" edge will be the y-axis.

Step Three: Pick a pair of x and y values from your table. Find that value on the x-axis, and, using a carpenter's square or drafting triangle, draw a perpendicular line from that point. Do the same thing for the y value. Where the lines intersect, make a dot. Do this for each pair of x and y values in your table.

Step Four: Draw a smooth curve through the points.

Step Five: Make a pattern by cutting the posterboard along the curve.

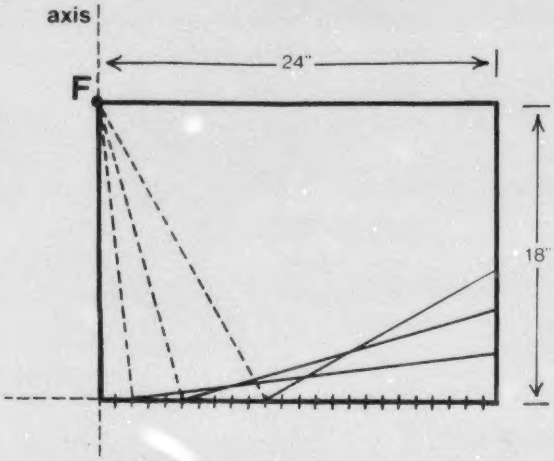
Team Two: Constructing a Parabola Using a Carpenter's Square

To do this, you will need:

☐ piece of posterboard at least 18" by 24", half the size of the side of the cooker you're going to make. Be sure it has at least one square (90°) corner.

☐ straightedge, such as a meterstick

☐ carpenter's square or large drafting triangle



Procedure

Step One: Lay the paper down so that the square corner is at the lower left hand corner and the 24" side is at the bottom. The upper lefthand corner will be the focus point. The short side of the paper will be the axis of the parabola. Measure 18" down from the focus and draw a line perpendicular to the axis. If your paper is exactly 18" wide, the lower edge of the paper will be the line and you won't have to draw it.

Step Two: Mark off 15 points 1" apart all across the line you drew, starting with the lower left-hand corner. (If your paper is exactly 18" wide, these points will be marked along the bottom 24"-long side of the paper.) Call these points "dots."

Step Three: Using a straightedge, such as a meterstick, draw lines from the focus point to each of the dots.

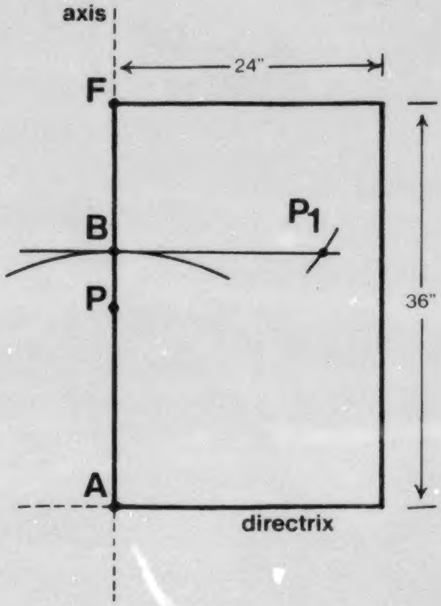
Step Four: Using the carpenter's square or drafting triangle, draw a line through each dot, perpendicular to the line from the focus point to the dot.

These lines will define a shallow curve. This is your parabola. Cut it out with scissors. To transfer the curve to the sides of the cooker, first trace one side of the pattern and then flip it over and trace the other.

Team Three: A Way of Constructing a Parabola

To do this, you will need:

- ☐ piece of paper at least 36" by 24", with at least one square (90^0) corner
- ☐ straightedge
- ☐ carpenter's square or large drafting triangle
- ☐ big compass



Procedure

Step One: Let the 36" edge of the paper be the axis of the parabola. The focus point F will be the upper left hand corner. Let the 90^0 corner be the lower lefthand corner. Since the solar cooker is to have a focal distance of 18", the parabola will cross the axis at a point 18" from F. Mark this point and label it P.

Step Two: Draw a line perpendicular to the axis and 36" from the focus point F (twice as far from the focus point as the parabola will be). (This line is called the *directrix.)* If your paper is exactly 36" long, this line will be the bottom edge of the paper. Call the point where the directrix and axis meet, A.

Step Three: Draw a line perpendicular to the axis, and crossing the axis anywhere between the focus point F and P, the point where the parabola meets the axis. Call the point where this line meets the axis, B.

Step Four: Set a compass to a radius equal to the distance between A, the point where the directrix and axis meet, and B, the point where the line you drew in Step 3 crosses the axis. Using the focus point F as the center of the circle, draw an arc crossing the line you drew in Step 3. The point P^1 where the circle crosses the line will be on the parabola.

Step Five: Repeat Steps 3 and 4, making more lines until you have enough points to reveal the parabola.

Team Four: A Way of Constructing a Parabola

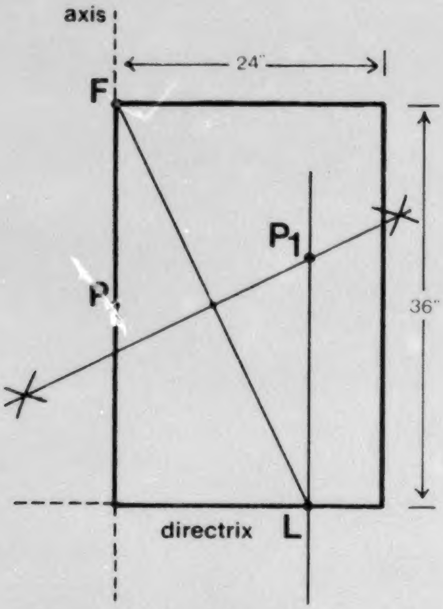
To do this, you will need:

☐ piece of paper at least 36" by 24", with at least one square (90°) corner

☐ carpenter's square or large drafting triangle

☐ straightedge

☐ big compass



Procedure

Step One: The 36" side of the paper will be the axis of the parabola. Let it be the left edge of the paper, with the square corner at the bottom left. Let the focus point (F) be the upper left-hand corner. Since the focal distance of the solar cooker is to be 18", the parabola will cross the axis at a point 18" from F. Mark this point and label it P.

Step Two: Draw a line perpendicular to the axis and 36" from the focus point F (twice as far from the focus point as the parabola will be). (This line is called the *directrix.)* If your paper is exactly 36" long, this line will be the bottom edge of the paper.

Step Three: Pick any point on the directrix and label it L. Draw a line through L perpendicular to the directrix. (Of course, the line will be parallel to the axis.)

Step Four: Draw a line from L to the focus point F. Bisect the line. Through the midpoint, draw a line perpendicular to the line L—F.

Step Five: The second line you drew in step four will cross the line you drew in step three. Label the point where they meet P^1. Point P^1 is on the parabola. Repeat Steps 3 and 4 to get more points of the curve. Draw a smooth curve through the points.

Team One: Making the Spit Supports

To do this activity, you will need:

☐ small saw

☐ ruler

☐ drill with a 1/2" bit

☐ piece of one-by-two lumber at least 39" long

Procedure

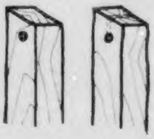
Step One: Cut 2 pieces of one-by-two, each 19" long.

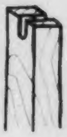
OLD CARPENTER'S PROVERB:
MEASURE TWICE, CUT ONCE.

Step Two: At the end of each piece, 1" from the top and in the middle of the nominal 2 inch side of the board, drill a 1/2" hole. (See drawing below.)

Step Three: At the end of *one* of the pieces, saw down from the top to the edges of the hole to make a slot at least 1/2" wide.

You are done. Take the pieces to your teacher.





Team Four: Making the Framework

To make the framework, you need:

☐ one-by-two lumber, about 11 feet

☐ saw

☐ pencil

☐ try square

☐ ruler

OLD CARPENTER'S PROVERB:
MEASURE TWICE, CUT ONCE.

Pick one person to be First Measurer, another to be Second Measurer, and another to be Sawyer. First Measurer measures off the piece. At the point where the wood is to be cut, First Measurer uses the try square to draw a straight line showing where the saw cut is to be. Then, Second Measurer measures again to see if First Measurer was right. Sawyer then cuts off the piece. Take turns doing the different jobs.

Measure off and cut:

2 pieces of one-by-two 27" long

1 piece of one-by-two 26 3/4" long

1 piece of one-by-two 44" long

Team Two: Making the Reflector

To make the reflector, you will need:

☐ aluminized Mylar or aluminum foil

☐ thin corrugated cardboard

☐ crayon

☐ pair of scissors

We need enough Mylar or foil to cover the reflector. The reflector is 27" by 55". If your Mylar is wide, cut a piece 29" by 55". If your Mylar is in a roll about 8" wide, cut 4 pieces 55" long (enough to cover the reflector.)

Step One: Draw a centerline neatly across the middle of the Mylar with a crayon. The centerline should be perpendicular to the 55" side and divide it in two. (If you have used a roll of 8" Mylar, draw centerlines through all 4 pieces.)

Try to get as few fingerprints, creases, and wrinkles in the Mylar or foil as possible.

Step Two: Cut a piece of corrugated cardboard 27" by 55", so that the corrugations run in the 27" direction.

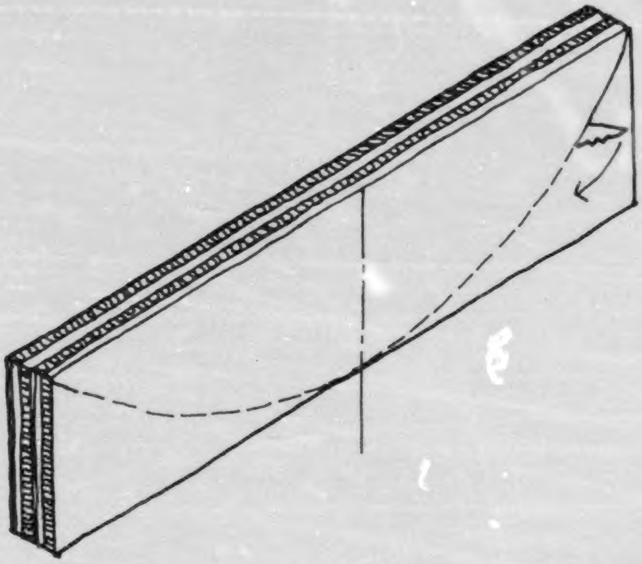
Step Three: Draw a center line on both sides of the cardboard. The centerline should be perpendicular to the 55" side and divide it in two.

You have finished. Call your teacher.

Team Three: Making the Sides of the Cooker

To make the sides of the cooker, you will need:

- ☐ ruler
- ☐ crayon or marker
- ☐ white glue
- ☐ cardboard saw
- ☐ parabola pattern
- ☐ carpenter's square
- ☐ corrugated cardboard



You are going to make the sides of the cooker.

Step One: To do this, you need 2 pieces of corrugated cardboard, each 12" by 48".

If you do not have pieces that big, make them by gluing smaller sheets in two layers, the way plywood is made. Turn the top sheet so that its corrugations run at right angles to the corrugations of the bottom sheet. Be sure you don't get joints in the same place on both top and bottom layers.

Using a straightedge, trim the glued-up sheets of 2-layer cardboard so that you have at least one straight 48" side on each one.

Step Two: Mark a centerline in the middle of each piece of cardboard (24" from each end) at right angles to the straight side.

Step Three: Lay the axis of the parabola pattern along the centerline on one of the pieces of cardboard, with the curve just touching the side opposite the straight 48" side. Trace the curve of the parabola onto the cardboard using a crayon or marker.

Step Four: Flip the parabola pattern over, keeping the axis on the centerline, and trace the other half of the curve.

Step Five: Hold the two pieces of cardboard together and cut along the line of the parabola.

You have finished. Tell your teacher.

Gas From Biomass

Note: This project takes weeks to achieve results; plan on going on to new topics before reaching closure on this one.

Objectives

This lesson contributes to students' understanding of the following ideas:

Methane can be made from waste materials through biological processes.

Format of the Lesson

(This is a teacher demonstration)

Discuss energy content of manure

Discuss decomposition

Discuss purpose of different parts of apparatus, and assemble

Charge with manure

(Then, at intervals of several days, have the class observe what has happened. Eventually ignite the gas, and disassemble).

Materials Needed

starter starter, like the starter in making sourdough bread, is any material that contains a large number of the particular microorganisms we need. The digester will work without starter, but adding the starter shaves about two weeks off the wait before results become evident. Make the starter by putting some manure and several handfuls of grass clippings in water in a loosely stoppered bottle. Let sit for 6-8 weeks in a place where the temperature is between 70 and 90 degrees Fahrenheit.

two-hole stopper to fit bottle
OR
wide-mouth bottle cap fitted with two plastic 3/16-inch hose barb fittings

bottle one gallon, glass or plastic, but it should be clear so that students can observe what happens inside.

glass tubing this can be found in a high school chemistry lab; if you aren't familiar with heating tubing to bend it, ask a teacher or student to make you a manometer and burner tip. These pieces are indicated in the drawing below.

3/16-inch plastic tubing about 25¢ a foot.

T-connector 3/16-inch hose barbs plastic.

ring stands with clamps. Optional, but convenient for holding the glass tubing.

rubber tubing a few feet.

pinchcock

manure

plant matter see below.

vinegar a few tablespoons.

storage container for the gas produced. A large plastic bag, if you can get a heavy one without holes. Another possibility is the plastic liner from the cartons in which milk is delivered to restaurants and school cafeterias.

for each flashback preventer

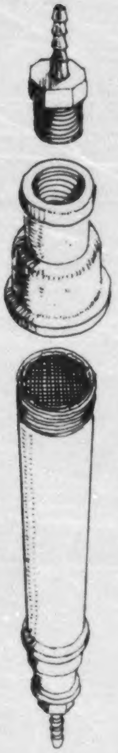
brass strainer cloth, 80 mesh about 60¢ a running inch (12 inches wide) at hardware stores.

3/16-inch hose barb to ½-inch male pipe fitting two, plastic. About 45¢ each.

three-inch nipple, ½" pipe copper is about $1.85.

bell reducer, ¼-inch to ½-inch In brass, these are $2 each. Maybe you can find them in plastic.

solder and soldering supplied see note below



A Review of Precautions

Methane is an energy-packed fuel and requires respectful handling. A mixture of one part methane to 12-13 parts of air will ignite explosively. To discourage this, one wants to prevent the accumulation of a large volume of methane-air mixture, and one wants to keep flame from travelling into the stored gas. Preventive measures include:

1. The manometer not only indicates the pressure, but also acts as a safety valve. This function is lost if the tube is permitted to become clogged.

2. A long narrow burner tip with a small orifice helps to prevent flame from traveling back into the gas supply.

3. Squeezing out as much air as possible in setting up the apparatus is essential. Make tubing runs as short as possible, of diameters no larger than necessary.

4. Putting a flashback preventer in line between the burner tip and the storage compartment can prevent flame from traveling back into the storage compartment.

If you decide to use a flashback preventer, it must be made in a metal shop prior to class. Square off both ends of the metal nipple with a file. Apply flux to the pipe edge. Using a torch or very heavy soldering iron, tin the exposed pipe edges at each end of the pipe, taking care not to get solder on the threads. Lay a piece of strainer cloth over the pipe; don't make it too large because the cloth dissipates heat very rapidly. Apply flux to the edges of the strainer cloth. Solder the strainer cloth to the pipe, making sure the solder seals the strainer cloth to the pipe all around the pipe edge. Repeat the procedure for the other end of the pipe. Snip off any excess strainer cloth projecting over the edge of the pipe. With a small file, restore the pipe threads where they have been filled-in by solder. Screw the bell reducers onto the nipple, using joint compound or teflon tape. Finally screw the hose barbs into the bell reducers. The flashback preventer is now complete.

Preliminary Discussion

(A down-home example of anaerobic methane production with which everyone is familiar is flatulence – e.g., ask the students, what happens after you eat beans? This approach is too ribald for most classes – perhaps most teachers – use your good judgment.)

We need oxygen to get energy from the food we eat. But some simple living things don't need oxygen to get energy from complex organic molecules.

Examining the Raw Materials

Take the organic matter which you will decompose. Let's suppose you are using dried steer manure from a nursery.

Identify the substance for the students. Ask where it came from. (ANS: Cow droppings, solid excretia of cows – whatever terms are meaningful to the class.) Ask, before the cow, where did it come from? (ANS: Plants the cow ate.)

The cow got energy from the plant matter by taking molecules from the food into its body. Ask, is there any energy left in the cow manure? This can be a topic of much discussion. Students with farm backgrounds may point out such clues as: manure generates heat when it is composted; some insects seem to live in cow droppings. An obvious clue is that energy can be released by burning dung as the pioneers did buffalo chips or as the people of India do today.

Are there living things in the manure? Many students will recognize that there are "germs" in unsterilized manure, i.e., microscopic forms of plant and animal life.

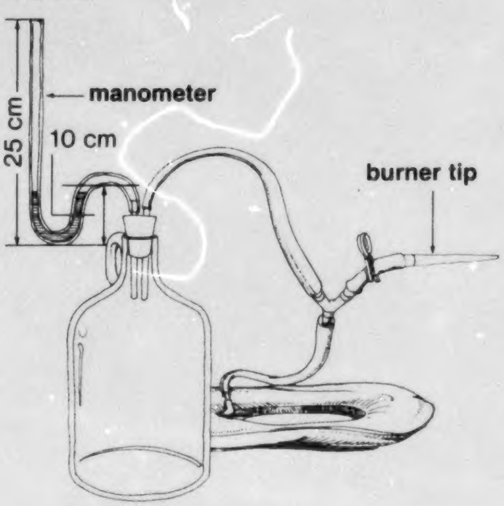
If we left a cow dropping alone in a field, what would happen to it? (ANS: Eventually it would disappear – decay.) What causes decay? (ANS: The microscopic plants and animals.) These organisms are called "decomposers."

It turns out that the bacteria of decay in air mostly produce the same respiration products we do: water and carbon dioxide. But if the decay takes place where there is no air a different kind of bacteria thrive. We call this, anaerobic (without air) decomposition.

The Apparatus

We can capture some of the energy in waste materials by using the microorganisms of anaerobic decay. We will use them to produce methane, the main component in natural gas.

Assemble the apparatus. It should look like this.



Into a clear gallon jar put some grass clippings and a few cupfuls of dried manure, covered with water. It is helpful but not essential to run this mixture through a blender to ensure a smooth slurry. Remind the students there is chemical energy in the manure and clippings — ask where it came from.

Adding a few tablespoons of vinegar will help to acidify the slurry and speed the creation of a favorable environment for the methane producing bacteria.

Add the starter, explaining how you made it and that this liquid is rich in the particular kind of microorganisms we want.

Cap the bottle with the 2-hole stopper and add water to the manometer, explaining that it serves as both a pressure gauge and safety valve. Connect the Y, burner tube and storage tank. Use a pinchcock to close off the burner tip.

Find a spot where the digester can be left undisturbed for a number of weeks. If temperature requirements can be met, outside is best — in any case, not near an open flame. The ideal temperature range is from 85 - 105°F; below 60°F, nothing happens.

From time to time, check the digester to see if gas is forming, and that the tubes have not been blocked by slurry.

Examining the Results

After a few weeks, the storage chamber will begin to fill with gas. Initially this will be mostly carbon dioxide.

Place a pinchcock between the digester and storage bag; remove the one between the storage bag and burner tip. Using a match, try to light the escaping gas. While it is carbon dioxide, you will be unable to. The second bagful, however, should ignite. To make the flame visible to the students, hold a piece of black construction paper behind the burner tip. Be prepared to reignite the flame.

Projects for Independent Investigation

1. Especially at the beginning, the gas produced by the fermentation is rich in carbon dioxide, which doesn't burn. Of course, that dilutes the heating value of the gas. Can you devise a practical way of removing the carbon dioxide from the gas? (Think back to the experiments in Unit Two.)
2. What is the optimal acidity? . . . temperature? How could you find out?
3. What kinds of organic waste that might be decomposed for gas are available in your community?
4. Are the leftovers good fertilizer or not? Determine an answer experimentally.
5. Why is methane sometimes called "marsh gas?"

Unit Six
Energy in the United States

Narrative Overview

Why We're Teaching This

Previous units occasionally tried to give students some historical perspective on energy's role in human affairs. This perspective is necessary to any evaluation of our present situation. For example, many think our era's uniqueness—the fossil fuel "blip" in human history—confers a sobering responsibility on our generations.

In order to bring out the changing role of energy in daily life and the origins of our present patterns of energy extraction and use, this unit focuses on the history of the United States, the part of the past with which students are most familiar. In important respects, America's energy history does **not** resemble that of, say, the nations of western Europe. For the most part, we will be studying social history.

It would be wrong for a unit such as this to simply provide facts about energy use in earlier times. Learning history must include learning to behave like a historian. Several lessons take as their subject how the historian attempts to discover the truth about events long past from the records available to her. Numerous readings in primary sources provide an excellent way of developing students' skill in critical reading. Each reading is accompanied by simple recall questions ("Reading Carefully"), but also by questions requiring analysis and synthesis ("Thinking It Over"), and sometimes research in other sources.

What We'll Teach and How

1. A Chronological Tour of U.S. Energy History

Americans in earlier times had many of the same needs we have today (such as cooking, preserving food, lighting, keeping warm, transportation), and they used energy to meet those needs. Students can use their familiarity with their own needs as a starting point in analyzing primary sources to discover what energy sources were used by previous American societies, and how they used them.* Acting out the activities of Americans in earlier generations is an additional way of acquiring some sense of what daily life was like, and it is effective with students who have difficulty relating to the printed word.

As we become familiar with life in succeeding periods certain trends begin to emerge, such as

energy sources change from wood and muscle to coal to petroleum

labor-saving machinery is increasingly used

use of transportation and communication increases

1600s: The archaic language of Captain John Smith's list of what settlers should bring to Virginia introduces students to historical research, and reveals the settlers' dependence on human muscles, hand tools, and gunpowder.

1700s: Labor-short America early developed a tradition of invention, exploiting the available energy sources with greater and greater efficiency. Thomas Jefferson made major improvements in the horse-drawn plow, for which he received a medal from the French government. In readings, Oliver Evans and a co-worker describe the world's first automated, water-powered flour mill. Benjamin Franklin describes a stove he has invented to alleviate Philadelphia's fuelwood crisis. (How can an historian be sure there really was a crisis, and that Franklin didn't just invent it to sell stoves? Another contemporary writer provides independent corroberation.)

*Readings which focus on a particular energy source, such as wood, coal, oil, or gas, are provided in Unit Three.

1800s: European travelers left descriptions which are a good source of observations of life in America's wooden age. The English author Marryat (**Midshipman Easy**) describes forms of transportation and industry.

By the the middle 1800s major changes were under way. Mark Twain writes about changes on the Mississippi waterfront, as railroads replace steamboats and coal replaces wood. By the late 1800s mechanization was reaching the life of the average American, even on the Midwestern frontier lovingly described by Laura Ingalls wilder.

1900s: The turn of the century brings societies that seem quaint, but recognizably our own. Early motorists describe the impact of the automobile on their lives and their communities. Electricity provides a light that replaces kerosene, and the rise of electricity begins, bringing telephones, radio, and television. Since many objects from this era have survived, a new type of activity is possible as students look for physical evidence of the past in their own community.

2. The U.S. Energy Situation Now

As we come to the years after World War II, more of the topics resemble current events—changes in pollution, how air conditioning changed the swings between peak and base demand for electricity, the development of our reliance on imported petroleum. Primary source materials give way to teacher presentations and other types of exercises, like interviews of older people and a paper-and-pencil activities. (For example, a puzzle on how fast a centralized power source can add generating capacity, part of an investigation of the constraints on the rate at which our energy system can change.)

Reviewing U.S. energy history, we compare our use of energy to that of other countries, relating it to resources and productivity.

To review and summarize the present U.S. energy situation students study the energy flow diagram in the student booklet. This activity can lead to students constructing a similar diagram for their own households, using previously compiled data.

[This overview is provided to give the reader some idea of the sequence. Some of the activities and lessons mentioned are not included in the present edition. If you are interested in a particular activity mentioned, write to us, describing the activity requested and your subject and grade level. Promise to provide a full report on the results should you decide to try the activity with your students, and we will send you the current draft version.]

Energy Sources Used by the Early European Settlers

Objectives

Students describe the energy sources used by early settlers.

Students experience how a historian can draw inferences from contemporary written sources.

(optional) Students contrast energy use by European settlers with sources and uses by Native Americans.

Materials Needed

reading **Off to the Wilderness,** one per student. (Collect the copies at the end of the period for re-use.)

Format of the Lesson

Focus class' attention on energy sources in daily life of early settlers.

Discuss how historians find out about the past.

Read the selection.

Discuss what energy sources are implied in the reading.

Optional: compare with energy sources used by Native Americans, and their technology.

CONDUCTING THE LESSON

A Historical Problem

Point out to the class that all societies require energy sources. Knowing what energy sources a society uses and how the society can use those sources can tell us a great deal about that society.

Ask the students what energy sources were used by the early European settlers of North America. Guesses may include muscle power, firewood, horses, and so on. Accept all the guesses with minimal discussion.

How Do Historians Get Evidence?

Ask the class how we can find out which of these guesses are correct. Today, more than 300 years later, we can't go see for ourselves what energy sources the settlers used. How can we find out what the truth is?

One way is to examine old writings. (Remember that there **are** others, for example excavation.)

Point out to the class that it is not always easy to understand something written a lon time ago. Archeologists have found written materials in languages that we can't translate today. Even writings in English several hundred years ago are difficult to read, because handwriting has changed, spelling has changed, the meanings of some words have changed, and some words are no longer used.

Tell the class that you will give them an old document that may throw some light on what energy sources were used by the first settlers of Virginia. Divide the class into working groups of three, permitting quiet discussion within the group. Give each student a copy of the reading, **Off to the Wilderness.**

Preparing to Read the Document

Reassure the students that this is a difficult document that anyone would have to pick his way through. Real historians usually face similar kinds of uncertainty. (A reading level for this reading would be meaningless, owing to the lack of sentences and the strange vocabulary. Students will be decoding, rather than reading.)

Ask if any student knows who Captain John Smith was. Review that he was a leader of the early English settlements in Virginia. Perhaps one of the students remembers the Pocohontas story.

Tell the students that the prices are given in pounds (£), shillings (s), and pence (d). Identify the abbreviations. Tell them that there are 12 pence to a shilling and 20 shillings to a pound.

Encourage the students to guess at the meaning of strange words. Direct their attention to the last two items in the paragraph about Canvas. Have them find "ells of course Canvas" and "1 course rug." What does the word c-o-u-r-s-e mean? (ANS: It is the way Smith spelled "coarse.")

Ask students to look at the next-to-last item in the list of food, just above vinegar, where it says, "one gallon of o-y-l-e." What is this? (ANS: Cooking oil.)

So, in reading this we have to do some detective work.

State the Problem Again

Give the students ten minutes to read over the list, searching for clues as to what energy sources the settlers in Virginia used.

Discussing the Evidence

The course of the discussion from this point depends on the resourcefulness your students have shown in attacking the document. The discussion should bring out that the principal sources were

Source	Evidence
human muscle power	food: "meal, pease" etc. hand tools: "howes, axes" etc.
firewood	"feling axes," pot, spit, etc.
gunpowder	"20 pound of powder"

And there is **no** evidence for a source we might expect, animal muscle power.

A typical course of discussion might be:

Human Muscle Power

Direct students' attention to the paragraph at the bottom of the first page. What are these items? (ANS: Food for a year for one man.)

Does anything in the document suggest that the settlers would be doing a lot of hand work?

Look at the lists of tools. What kind of tools are they? Chainsaws? (ANS: All hand tools.) For what kinds of activities? (ANS: Farming. Felling trees. Building.)

Animal Power?

Did the people use draft animals?

What kinds of tools do you need to use animal power? (ANS: Horseshoe nails, horseshoes, saddles.) Are saddles listed?...are horseshoes?...harnesses, yokes or anything like that?

Do you think it's reasonable to conclude that these settlers did not depend on animal power?

Did the people of Europe use oxen, mules, donkeys and horses at this time? Are they mentioned on the list? (ANS: Yes, at the end the list mentions "Kine and Goats.") Can you think of any reasons why the average settler wouldn't yet have any oxen, mules or horses?

Another Kind of Chemical Energy

In the list there is evidence of another energy source, a kind of chemical energy. What? (ANS: Gunpowder.) What did they use that for?

Optional Topic: Contrast with the Native Americans

If time remains, you may wish to ask the students how this picture of which energy sources the settlers used and how they used them might differ from that of the Native Americans living in the same area. Did the additional sources, the additional ways of using those sources (e.g. iron tools), give the Europeans a greater ability to exploit the resources of the forest than the Native Americans had? How?

Collect the copies of the reading for reuse.

Projects for Independent Investigation

1. In many parts of the country, there are "living museums" where the staff demonstrates how people in earlier times earned their living. Some of these are located in areas of early settlement. Visit such a museum and describe it to the class.

2. Learn how to do something as it was done by the early settlers, then demonstrate it for the class. For example:
   cook a dish in a fireplace
   make thread
Your library can provide books that describe such chores.

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left blank.
Lesson
continues.

➡

Off to the Wilderness

Suppose you were going to a wilderness where you could depend only on yourself. What would you take with you?

The people who left England to settle the new colony of Virginia in the early 1600's had just such a problem. To guide them, the leader of the colony, Captain John Smith (remember Pocahontas?) made the following list. Read it over, then answer the questions.

A particular of such necessaries as either private families, or single persons, shall have cause to provide to goe to Virginia, whereby greater numbers may in part conceive the better how to provide for themselves.

Apparell for one man, and so after the rate for more.

A Monmoth Cap.		1s.	10d.	
3 falling bands.		1s.	3d.	
3 shirts.		7s.	6d.	
1 Waste-coat.		2s.	2d.	
1 suit of Canvase.		7s.	6d.	
1 suit of Frize.		10s.		Frize = Frieze, a coarse woolen cloth
1 suit of Cloth.		15s.		
3 pair of Irish stockings		4s.		
4 paire of shooes.		8s.	8d.	
1 paire of garters.			10d.	
1 dozen of points.			3d.	Points = laces for fastening clothing, similar to shoelaces
1 paire of Canvas sheets.		8s.		
7 ells of Canvas to make a bed and boulster, to be filled in Virginia, serving for two men.		8s.		Ell = a unit of length, about a yard Boulster = a large pillow
5 ells of course Canvas to make a bed at Sea for two men.		5s.		
1 course rug at sea for two men.		6s.		
	4£.			

Victuall for a whole yeare for a man, and so after the rate for more.

8 bushels of meale.		2£.		Meale = wheat flour
2 bushels of pease.		6s.		
2 bushels of Otemeale.		9s.		
1 gallon of Aquavitae.		2s.	6d.	Aquavitae = a strong alcoholic beverage
1 gallon of oyle.		3s.	6d.	
2 gallons of Vinegar.		2s.		
	3£.	3s.		

From **The General History of Virginia** by Captain John Smith, 1624; The Fourth Book.

Armes for a man; but if halfe your men be armed it is well, so all have swords and peeces.

1 Armor compleat, light.		17s.	
1 long peece five foot and a halfe, neere Musket bore.	1£.	2s.	
1 Sword.		5s.	
1 Belt.		1s.	
1 Bandilier.		1s.	6d.
20 pound of powder.		18s.	
60 pound of shot or Lead, Pistoll and Goose shot.		5s.	
	3£.	9s.	6d.

Peece = a firearm

Bandileer = a broad leather belt worn over the left shoulder

Tooles for a family of six persons, and so after the rate for more.

5 broad howes at 2s. a peece.	10s.	
5 narrow howes at 16d. a peece.	6s.	8d.
2 broad axes at 3s. 8d. a peece.	7s.	4d.
5 feling axes at 18d. a peece.	7s.	6d.
2 steele handsawes at 16d. a peece.	2s.	8d.
2 two handsawes at 5s. a peece.	10s.	
1 whipsaw, set and filed; with box, file and wrest.	10s.	
2 hammers 12d. a peece.	2s.	
3 shovels at 18d. a peece.	4s.	6d.
2 spades at 18d. a peece.	3s.	
2 Augers at 6d. a peece.	1s.	
6 Chissels at 6d. a peece.	3s.	
2 Percers stocked 4d. a peece.		8d.
3 Gimlets at 2d. a peece.		6d.
2 Hatchets at 21d. a peece.	3s.	6d.
2 frowes[2] to cleave pale 18d. each.	3s.	
2 hand Bills 20ds. a peece.	3s.	4d.
1 Grindstone.	4s.	

Two handsawe = a saw for two hands, i.e. one person at each end.

Frowes = froes.

Nailes of all sorts to the value of	2£.		
2 Pickaxes.		3s.	2s.
	6£.	2s.	8d.

Household equipment for a family of six persons, and so for more or lesse after the rate.

1 Iron pot.		7s.	
1 Kettell.		6s.	
1 Large Frying-pan.		2s.	6d.
1 Gridiron.		1s.	6d.
2 Skellets.		5s.	
1 Spit.		2s.	
Platters, dishes, spoones of wood.		4s.	8d.
	1£.		

For Sugar, Spice, and Fruit, at Sea for six men.

12s. 6d.

So the full charge after this rate for each person, will amount to about the summe of

12£ 10s. 10d.

The passage of each man is

6£.

The fraught of these provisions for a man, will be about halfe a tun, which is

1£. 10s.

So the whole charge will amount to about 20£.

Now if the number be great; Nets, Hooks, and Lines, but Cheese, Bacon, Kine and Goats must be added. And this is the usuall proportion the Virginia Company doe bestow upon their Tenents they send.

Reading Carefully

1. Smith lists two kinds of chemical energy. What are they?

2. Many tools are listed. What provided the power for the tools?

3. Could you live for a year on the food Smith lists? (The question isn't whether you would want to.) What other food sources are implied by the list of tools?

4. Why is "sugar, spice, and fruit" needed at sea?

5. What raw materials are represented? What are the tools made of? How was energy important in obtaining these raw materials? In which forms was the energy obtained?

Corroboration

Why This Lesson

By the end of the colonial period, urbanization was already occurring in colonial North America; Philadelphia was now the second-largest city in the English-speaking world. Concentration of population and increasing manufactures created new problems in the use of wood as the primary fuel, just as they have in today's developing countries. One response was invention.

This episode provides a good example of how an awareness of historical incidents can further our understanding of our present problems. Supply and demand, innovation, and efficiency played much the same roles in the petroleum crisis of the 1970s as they did in Philadelphia's fuel crisis of the 1740s.

This particular reading also gives us an opportunity to investigate the limits and methods of the historian's use of primary source materials.

Objectives

This lesson contributes to students' understanding of the following generalizations.

Wood was the primary fuel in colonial America, used for heating, cooking and lighting, as well as in industry.

As the colonies' population grew and their industries developed, consumption of wood increased.

As supply fell and demand increased, especially near cities, the price of firewood rose.

One response to the growing scarcity was to improve the efficiency with which the firewood was used.

Historians compare a variety of contemporary records in seeking to determine the truth about the past.

Materials Needed

reading **Benjamin Franklin's Stove,** one per student

reading **Pehr Kalm's Researchers**, one per student

Introducing the Reading

Introduce the reading by asking who Franklin was and what he did. One of Franklin's roles was that of inventor, and one of the things he invented was the Franklin stove. Pass out the reading.

(For your own information, note that today many people call any free-standing iron fireplace which is open in the front a Franklin stove. That is not at all what Franklin invented, as the introduction describes.)

The Franklin reading may be divided into into three parts:

The firewood crisis (the first page)
Improving the efficiency of firewood use (item 6 and the footnote on the second page)
The disadvantages of the ordinary fireplace (pages 2 and 3)

If you do not wish your students to read the entire piece, have them skip the introduction and read Franklin's first four paragraphs.

You may wish to give your students overnight to read the entire selection.

Discussing the Franklin Reading

Discuss the following sequence of questions:

What does Franklin say has happened to the price of firewood? How does he explain the increase? What does he suggest be done about it?

(If students have read the entire piece) Would you like to heat your house exclusively with a fireplace? What would some of the disadvantages be?

Franklin describes the efficiency of his stove, comparing it to an ordinary fireplace. How much more efficient is the stove?

Why did Franklin write this book?

Planting the Seeds of Doubt

Ask the class if we can always believe what an eyewitness says. Do eyewitnesses always remember accurately? Try an experiment by asking each member of the class to write on a piece of paper, say, what was served in the cafeteria one week ago. Compare the answers. Can an eyewitness have a reason for wanting to distort the truth, or even lie? Can they do so unintentionally? Conclude that the fact that a report is made by someone who was actually there does not **guarantee** that the report is accurate.

Franklin says that the price of firewood rose. Should we accept this as true?

Might Franklin have had any reasons to exaggerate the scarcity of firewood?

Was Franklin selling anything? (ANS: Yes, stoves.)

If a person believed firewood prices had risen and were likely to continue rising, would that make him more likely to buy one of Franklin's stoves?

So, do you think we should simply take Franklin's word that there was a firewood crisis in Philadelphia in 1744? How can we be more certain about what happened?

A student may suggest that we look at government statistics. Point out that in those days, few statistics of any kind were kept. Even today it is very hard to keep track of sales of firewood, since there are so many buyers and sellers, and a great deal of wood is consumed by the person who cut it.

If students don't suggest finding another witness, ask what happens in a courtroom. Conclude that a good strategy is to try to find several different witnesses who agree.

Pass out the reading, **Pehr Kalm's Researches.** Ask students to read the first section, titled "Fuel."

As estimated by a Fry count, the reading level of this section is grade 8. Phrases whose meaning you may wish to discuss are:

people of quality and fortune
joiners, coachmakers . . .

Discussing Pehr Kalm's Firewood

When students have finished the reading, ask whether Kalm agrees with Franklin that the price of firewood has risen. Are Kalm's reasons the same as Franklin's?

As historians, what do you think now? Did the price of firewood rise in Philadelphia in the middle 1700s?

Sum up that this is one of the ways historians work. The more evidence brought to bear on a point, the better.

The questions included at the end of the reading raise other topics which you may wish to consider.

For homework, students may read the second selection from Pehr Kalm, "Petroleum."

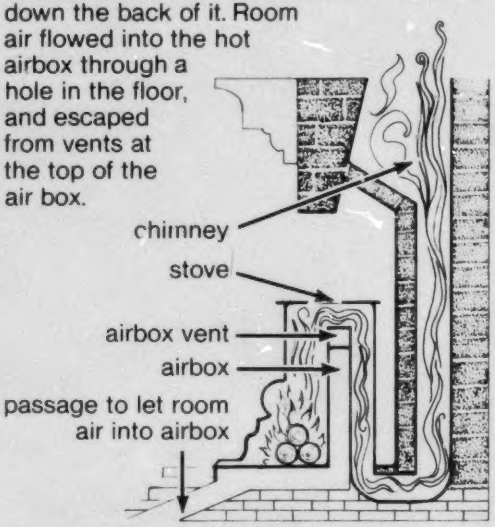
Benjamin Franklin's Stove

Benjamin Franklin was the most famous American of his day. Not only was he a great scientist, but also the most popular American writer, our ambassador to our most important foreign ally, a successful businessman, and one of the people who invented the system of government we still use 200 years later.

Franklin was also an inventor who used his understanding of science to solve people's problems. One of his inventions that is still used is the Franklin Stove. In a Franklin Stove, the hot air from a wood fire is drawn down around an iron chamber in the back of the stove. As this happens, much of the heat in the air is transferred to the iron and then to the air in the iron box, which is let out into the room.

The description below is taken from an advertising pamphlet Franklin wrote to sell his stoves.

The secret of Franklin's iron fireplace was a false back, which was the front side of the hollow airbox. Smoke from the fire flowed up the front of the airbox and then down the back of it. Room air flowed into the hot airbox through a hole in the floor, and escaped from vents at the top of the air box.



From: An Account of the Newly Invented Pennsylvanian Fire-Place

by Benjamin Franklin, Philadelphia, 1744

In these Northern Colonies the Inhabitants keep Fires to sit by, generally Seven Months in the Year; that is, from the Beginning of October to the End of April; and in some winters near Eight Months, by taking in part of September and May.

Wood, our common Fuel, which within these 100 Years might be had at every Man's Door, must now be fetch'd near 100 Miles to some Towns, and makes a very considerable Article in the Expense of Families.

As therefore so much of the Comfort and Conveniency of our Lives, for so great a Part of the Year, depends on the Article of FIRE; — since Fuel is become so expensive, and (as the Country is more cleared and settled) will of course grow scarcer and dearer; any new Proposal for Saving the Wood, and for lessening the Charge and augmenting the Benefit of Fire, by some particular Method of Making and Managing it, may at least be thought worth Consideration.

The New Fire-Places are a late Invention to that purpose (experienced now three Winters by a great Number of Families in Pennsylvania) of which this Paper is intended to give a particular Account.

The Advantages of this Fire-Place

Its Advantages above the common Fire-places are:

1. That your whole Room is equally warmed; so that People need not crowd round the Fire, but may sit near the Window and have the Benefit of the Light for Reading, Writing, Needlework, etc. They may sit with Comfort in any Part of the Room; which is a very considerable Advantage in a large Family, because all cannot conveniently come at One.

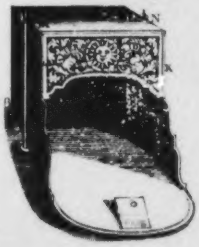
2. If you sit near the Fire, you have not that cold Draught of uncomfortable Air nipping your Back and Heels, as when before common Fires, by which many catch Cold, being scorched before and as it were froze behind.

3. If you sit against a Crevice, there is not that sharp Draught of cold Air playing on you, as in Rooms where there are Fires in the common way; by which many catch cold, whence proceed Coughs, Catarrhs, Toothaches, Fevers, Pleurisies and many other Diseases.

4. In Case of Sickness, they make most excellent Nursing-Rooms, as they constantly supply a Sufficiency of fresh Air, so warmed at the same time as to be no way inconvenient or dangerous.

5. In common Chimneys the strongest Heat from the Fire, which is upwards, goes directly up the Chimney, and is lost; and there is such a strong Draught into the Chimney, that not only the upright Heat, but also the back, sides and downward Heats, are carried up the Chimney by that Draught of Air; and the Warmth given before the Fire by the Rays that strike out towards the Room, is continually driven back, crowded into the Chimney, and carried up, by the same Draught of Air. – But here the upright Heat, strikes and heats the Top Plate, which warms the Air above it, and that comes into the Room. The Heat likewise which the Fire communicates to the Sides, Back Bottom and Air-Box, is all brought into the Room; for you will find a constant Current of Warm Air coming out of the Chimney-Corner into the Room. Hold a Candle just under the Mantle-Piece or Breast of your Chimney, and you will see the Flame bent outwards: By laying a Piece of smoking Paper on the Hearth, on either Side, you may see how the Current of Air moves, and where it sends, for it will turn and carry the Smoke with it.

6. Thus as very little of the heat is lost, when this Fire-Place is used, much less Wood* will serve you, which is a considerable Advantage where Wood is dear.



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* People who have used these Fire-places, differ much in their Accounts of the Wood saved by them. Some say five sixths, others three fourths, and others much less. This is owing to the great Difference there was in their former Fires: some (according to the different Circumstances of their Rooms and Chimneys) having been used to make very large, others middling, and others, of a more sparing Temper, very small Ones. While in these Fire-places (their Size and and Draught being nearly the same) the Consumption is more equal. I suppose, taking a Number of Families together, that two thirds, or half the Wood at least is saved. My common Room, I know, is made twice as warm as it used to be, with a quarter of the Wood I formerly consumed there.

7. When you burn Candles near this Fire-place, you will find that the Flame burns quite upright, and does not blare and run the Tallow down, by drawing towards the Chimney, as against common Fires.

8. This Fire-place cures most smoky Chimneys, and thereby preserves both the Eyes and Furniture.

9. It prevents the Fouling of Chimneys; much of the Lint and Dust that contributes to foul a Chimney being by the low Arch obliged to pass through the Flame, where it is consumed. Then, less Wood being burnt, there is less Smoke made. Again, the Shutter, or Trap-bellows, soon blowing the Wood into a Flame, the same Wood does not yield so much as if burnt in a common Chimney: For as soon as Flame begins, Smoke, in proportion, ceases.

10. And if a Chimney should be foul, 'tis much less likely to take Fire. If it should take Fire, 'tis easily stifled and extinguished.

11. A Fire may be very speedily made in this Fire-Place, by the help of the Shutter, or Trap-Bellows, as aforesaid.

12. A Fire may be soon extinguished, by closing it with the Shutter before, and turning the Register behind, which will stifle it, and the Brands will remain ready to rekindle.

13. The room being once warm, the Warmth may be retained in it all Night.

14. The lastly, the Fire is so secured at Night that not one Spark can fly out into the Room to do Damage.

With all these Conveniences, you do not lose the pleasant sight nor Use of the Fire, as in the Dutch Stoves, but may boil the Tea-Kettle, warm the Flat-Irons, heat Heaters, keep warm a dish of Victuals by setting it on the Top, &&.

Reading Carefully

1. How many months of the year did the people of Philadelphia (in the "Northern Colonies") keep fires?

2. Why does Franklin think wood is getting more expensive in big cities in 1744?

3. How much wood does Franklin claim the new fireplace will save?

4. Franklin says improving the fireplace will improve the lighting of the room. How?

5. From Franklin's list of improvements, what do you think the most disagreeable thing about heating a house with a fireplace would be?

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Pehr Kalm's Researchs

Pehr Kalm was a Swedish scientist, a student of the botantist Linnaeus. In 1748, the Swedish government sent him to North America to search for plants native to North America that might be useful in Swedish agriculture. After traveling through Pennsylvania, New York, New Jersey, and southern Canada, Kalm returned home in 1751.

Kalm was the kind of person who was interested in everything he encountered: he investigated not just the plants but also the people, the way they did things, and any other curiosities that came to his attention. In this he had the help of Benjamin Franklin and many other prominent people who befriended him.

Kalm published an account of his travels in three volumes, the first appearing in 1753 in Sweden. His anecdotes appealed to many readers and were soon translated into many other European languages, including this English version of 1770.

Fuel. The best wood for fuel in everybody's opinion is hickory, or a species of walnut, for it heats well; but it is not good for fences since it cannot well withstand rotting after it is cut. The white and black oaks are next in goodness for fuel. The woods with which Philadelphia is surrounded would lead one to conclude that fuel must be cheap there. But it is far from being so, because the large and high forest near the town is the property of some people of quality and fortune who do not regard the money which they could make from it. They do not fell so much as they require for their own use and much less would they fell it for others. But they leave the trees for times to come, expecting that wood will become much more expensive. However, they fell it for joiners, coach-makers and other artisans, who pay exorbitantly for it. For a quantity of hickory, eight feet in length and four in depth, and the pieces being likewise four feet long,* they paid at present eighteen shillings of Pennsylvania currency. But the same quantity of oak only came to twelve shillings. The people who came at present to sell wood in the market were farmers who lived at a great distance from the town. Everybody complained that fuel in the space of a few years, had risen to a price many times as much as it had been formerly, and to account for this the following reasons were given: the town had increased to such a degree that it was four or six times bigger and more populous than some old people knew it to be when they were young. Many brick kilns had been made hereabouts which require a great quantity of wood. The country is likewise more cultivated than it used to be, and consequently large forests have been cut down for that purpose; and the farms built in those places also consume a quantity of wood. Lastly, people melt iron out of ore in several places about the town, and this work goes on without interruption. For these reasons it is concluded that in future times Philadelphia will be obliged to pay a high price for wood.

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* A cord.

From *Travels in North America* by Peter Kalm; translated by John Reinhold Forster. Warrington, England: William Eyres, 1770.

Petroleum. Both Colonel Lydius and Mr. Rosbom and many others told me today about a kind of earth-oil which is to be had from the Indians allied with the English, in a place about three days' journey from the country of the Senecas. There is said to be there a small lake, about a musket's shot in length and breadth, upon the surface of which continually floats an oil. The natives go there in the spring when they find the lake almost covered with leaves which have fallen into it during the previous autumn and which are now saturated with oil. They set fire to them and allow them to burn up. The fire then continues to burn over the lake until all the leaves and all the oil on the water is consumed and only the water is left. They then take twelve-foot poles which they force down into the lake's bottom and an oil comes welling up from the bottom and the holes they have made therein. The bottom is not hard, but very soft. They skim with a spoon or scoop the oil which floats upon the water and preserve it in some vessel. Colonel Lydius accompanied me to the home of a man or gentleman who had some of this oil in a bottle. It was real petroleum and not at all different from what is sold at the apothecary's, except heavier; but I learned that this condition resulted from allowing it to stand several months in an open bottle, that is, without a stopper in the bottle. Its color is dark brown with a tendency toward red. The smell is absolutely that of petroleum or Jew's pitch.* The gentleman who had it in a bottle related that nothing was better for wounds than this. If a little were applied to the sore, it would heal within a short time, which he had experienced on his many journeys.

Reading Carefully

1. What did the people of Philadelphia use fuelwood for?

2. Was petroleum used as a fuel?

Thinking It Over

3. Was petroleum a new substance to Kalm? How did he happen to know about it?

4. Do you think the Indians' method of getting petroleum was easier or harder than drilling a well? Justify your answer.

5. Why would the "joiners, coach-makers and other artisans" be willing to pay more for wood than those who wanted wood to burn in their fireplaces?

Finding Out More Information

6. What is an apothecary? A joiner?

7. Kalm says, "...they leave the trees for times to come, expecting that wood will become much more expensive." Do you believe anyone has done this recently with other fuels, such as petroleum? How fast would the price have to be increasing for this to be a sensible strategy?

8. In many of today's books about heating with wood, you will find a list of the heating value of different species. Do these lists agree with the 1750 Philadelphians' opinions?

An Ordinance: Baltimore, Maryland; June 17, 1816

Whereas, it is represented to the Mayor and City Council of Baltimore by Rembrandt Peale, on behalf of himself and others, who have associated and formed a company by the name and title of "The Gas Light Company of Baltimore," that they are willing to contract to light the streets, squares, lanes and alleys of this City, in a more effectual manner, and with more safety, convenience and beauty by means of Carburetted Hydrogen Gas than they heretofore have been lighted by means of oil, without causing any increased expense to the City for lighting the same extent of streets or space; and the said company have prayed that the Mayor be authorized to contract with them for that purpose; and also, that they may be authorized to lay pipes for the streets, squares, lanes and alleys of the City; and the City Council being desirous of giving every reasonable assistance to promote the laudable views of the said company, and of having the City lighted in the most effectual manner, which the means[1] usually appropriated to that object will accomplish; therefore,

1. Be it enacted and ordained by the Mayor and City Council of Baltimore, That it shall and may be lawful for "The Gas Light Company of Baltimore" aforesaid, and they are hereby authorized to proceed to lay or cause to be laid along and under the streets, squares, lanes and alleys of the City, paved or unpaved, such and so many pipes as may be necessary to convey the gas from their manufactory or manufactories, which they are hereby authorized to establish and carry on with the City, until such permission be revoked, to and along any street, square, lane or alley which they shall propose to light, and also to supply with light any house or other place belonging to any individual or company adjacent to any such street, square, lane or alley in or along which the said pipes shall be repair or remove. Provided always, That the said company shall not in any manner injure or displace any pipe or pipes laid or to be laid by the Baltimore Water Company for the purpose of conveying water into or through any part of the city or precincts; and provided also, That "The Gas Light Company of Baltimore" aforesaid shall, immediately after laying, repairing or removing any pipe or pipes as aforesaid, in any street or part of a street, square, lane or alley, and always within two days after being thereto required by the City Commissioners, cause to be filled up, repaired and repaved, at their own expense, every such street, or part of a street, square, lane or alley as the said company may find it necessary to dig, impair or unpave for the purpose of altering, laying or removing any pipe or pipes as aforesaid; and if the said company shall omit or neglect to fill up, repair, or repave any such street, square, lane or alley, or any part thereof, or shall omit or neglect to remove and take away any dirt or rubbish which may remain after the laying, altering or removing such pipe or pipes, or after filling up, repairing or repaving as aforesaid, for the space of forty-eight hours after the time, which shall be limited by the City Commissioners in their notice for that purpose, the said

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[1] "means, that is, the amount of money.

company shall for every such omission or neglect forfeit and pay to the use of the City such sum not exceeding twenty dollars, as any Justice of the Peace for Baltimore County shall adjudge, on a warrant to be issued in the name of the Mayor and City Council of Baltimore against the president or other known officer of the said company, and also the sum of five dollars to be recovered as aforesaid, for every day they shall neglect or refuse so to do after the issuing of any warrant by a Justice of the Peace for the recovery of the said penalty of twenty dollars.

2. And be it enacted and ordained, That the said company shall be subject to all the penalties prescribed by the provisions of the ordiance entitled "An ordinance to encourage the introduction of water into the City of Baltimore," and of the several supplements thereto, so far as the same can within the intent and meaning of the ordinance be rendered applicable to the said company, and so far as they are not inconsistent with the provisions of this ordinance, and that the said company shall be particularly subjected to the provisions of the ordinance and supplements aforesaid respecting the repairing and repaving the streets, lanes and alleys through which the gas may be conveyed, removing the rubbish remaining from the laying or repairing the necessary pipes, and the repavement by the company of such streets, lanes or alleys as may be insufficiently repaved, or prove defective within six months from the time of their being repaved, and that the said penalties contained in the provisions of the said ordinance and supplements shall be recovered from the president or other known officer of the said company, before any Justice of the Peace in the mode hereinbefore prescribed and directed.

3. And be it enacted and ordained, That if any person shall impair, obstruct, displace or injure any pipe or any part of the machinery which shall be used or employed by the said company in manufacturing, conducting or conveying the said gas, or in any way impede the circulation, or cause a waste of the said gas, he or she, shall for every such offense, forfeit and pay such sum, not exceeding twenty dollars, as any Justice of the Peace shall adjudge, one-half to the use of the informer and the other half to the use of the city; and such person shall also be liable to pay damages for the injury which the said company may sustain.

4. And be it enacted and ordained, That the Mayor be, and he is hereby, authorized to contract with the said Rembrandt Peale and the other members of "The Gas Light Company of Baltimore," or with the agent or officer of the said company duly authorized for that purpose, to light the whole of the streets, squares, lanes and alleys of this city, or from time to time, for the lighting of any one street, or part of a street, square, lane or alley, as he may deem advisable, on such terms and conditions as to the Mayor shall appear reasonable: Provided, that no such contract shall be made for a longer period than one year, and also that the actual cost or expense of lighting the city in virtue or any such contract, shall not exceed the expense heretofore incurred for the same purpose, and the same proportion for lighting any street or streets, or any part of a street, unless the same shall be authorized by a future ordinance, and the Mayor is hereby authorized to pledge the faith of the city, that any contract or contracts made by him with the said company, under the restriction aforesaid, shall be continued, extended or renewed from year to year as long as the said company shall continue to light the city with as much economy, safety and as effectually as the same can or could be lighted by means of oil, or by any other company which may be established, or by any other means, and no longer: provided always, that the Mayor and the City Council of Baltimore reserve to themselves the right of annulling any such contract, and also of annulling and withdrawing any or all of the privileges granted by this ordinance if it shall at any time hereafter appear to the said Mayor and City Council, that the manufacture of gas or the use of it as a means of lighting the city, injures the health or endangers the property of the citizens in a greater degree than the use of oil for the same purpose.

5. And be it enacted and ordained, That "The Gas Light Company of Baltimore" aforesaid,may and they are hereby authorized, with the approbation of the Mayor and the consent of the owners or occupiers of houses fronting on or adjacent to any street, square, lane or alley, to attach the lamps, pipes or other apparatus to be used or necessary for lighting any such street, square, lane or alley, to any part of any such house or houses on such terms and conditions as may be agreed upon by and between the said company and the owner of occupier of such house or houses.

A Public Utility

1. Why did the city pass this ordinance?

2. What light source has the city been using up till now?

3. What special privileges does the ordinance give the company?

4. Which paragraph forbids people to interfere with the company's work?

5. Was there another public utility in Baltimore before Peale's gas company? What was it?

6. The ordinance forbids the gas company to interfere with certain other public services. What are they and how might the different services conflict? Do we still have this problem?

7. Paragraph 4 shows that the people who wrote the ordinance knew there was a risk in trying this new technology. What does it seem they thought the risks were? How were they going to decide if the benefits justified the risks?

8. Could Peale have established a service like this if the city had not passed an ordinance like this? If not, why not?

Transportation in America in the 1830s

Captain Marryat traveled around the United States by every means of transportation that was available in the 1830s. In one part of his book, he tells what he thinks about transportation in America.

But, before I enter into any remarks upon the various modes of travelling in America, it may be as well to say a few words upon the horses, which are remarkably good in the United States; they appear to be more hardy, and have much better hoofs, than ours in England; throwing a shoe therefore is not of the same consequence as it is with us, for a horse will go twenty miles afterwards with little injury. In Virginia and Kentucky the horses are almost all thoroughbred, and from the best English stock. The distances run in racing are much longer than ours, and speed without bottom is useless.

The Americans are very fond of fast trotting horses; I do not refer to rackers, as they term horses that trot before and gallop behind, but fair trotters, and they certainly have a description of horse that we could not easily match in England. At New York, the Third Avenue, as they term it, is the general rendezvous. I once went out there mounted upon Paul Pry, who was once considered the fastest horse in America; at his full speed he performed a mile in two minutes and thirty seconds, equal to twenty-four miles per hour. He took me at this devil of a pace as far as Hell Gate; not wishing "to intrude," I pulled up there, and went home again. A pair of horses in harness were pointed out to me who could perform the mile in two minutes fifty seconds. They use here light four-wheeled vehicles which they call wagons, with a seat in the front for two persons and room for your luggage behind; and in these wagons, with a pair of horses, they think nothing of trotting them seventy or eighty miles in a day, at a speed of twelve miles an hour; I have seen the horses come in, and they did not appear to suffer from the fatigue. You seldom see a horse bent forward, but they are all daisy cutters.

The gentlemen of New York give very high prices for fast horses; $1,000 is not by any means an uncommon price. In a country where time is everything, they put a proportionate value upon speed. Paul Pry is a tall grey horse (now thirteen years old); to look at, he would not fetch £10 – the English omnibusses would refuse him.

Talking about omnibusses, those of New York, and the other cities in America, are as good and as well regulated as those of Paris; the larger ones have four horses. Not only their omnibusses, but their hackney coaches are very superior to those in London; the latter are as clean as private carriages; and with the former there is no swearing, no dislocating the arms of poor females, hauling them from one omnibus to the other – but civility without servility.

The American stagecoaches are such as experience has found out to be most suitable to the American roads, and you have not ridden in them five miles before you long for the delightful springing of four horses upon the level roads of England. They are something between an English stage and a French diligence, built with all the panels open, on account of the excessive heat of the summer months. In wet weather these panels are covered with leather aprons, which are fixed on with buttons, a very insufficient protection in the winter, as the wind blows through the intermediate spaces, whistling into your ears, and rendering it more piercing than if all was open. Moreover, they are no protection against the rain or snow, both of which find their way in to you. The coach has three seats, to receive nine passengers, those on the middle seat leaning back upon a strong and broad leather brace, which runs across. This is very disagreeable, as the centre passengers, when the panels are closed, deprive the others of the light and air from the windows. But the most disagreeable feeling arises from the body of the coach not being upon springs, but hung upon leather braces running under it and supporting it on each side; and when the roads are bad or you ascend or rapidly descend the pitches (as they term short hills), the motion is very similar to that of being tossed in a blanket, often throwing you up to the top of the coach, so as to flatten your hat — if not your head.

The drivers are very skillful, although they are generally young men — indeed often mere boys — for they soon better themselves as they advance in life. Very often they drive six in hand; and if you are upset, it is generally more the fault of the road than of the driver. I was upset twice in one-half hour when I was traveling in the winter time; but the snow was very deep at the time, and no one thinks anything of an upset in America.

* * *

In making my observations upon the railroad and steamboat travelling in the United States, I shall point out some facts with which the reader must be made acquainted. The Americans are a restless, locomotive people: whether for business or pleasure, they are ever on the move in their own country, and they move in masses. There is but one conveyance, it may be said, for every class of people — the coach, railroad, or steamboat, as well as most of the hotels, being open to all; the consequence is that the society is very much mixed — the millionaire, the well-educated woman of the highest rank, the Senator, the member of Congress, the farmer, the emigrant, the swindler, and the pickpocket are all liable to meet together in the same vehicle of conveyance. Some conventional rules were therefore necessary, and those rules have been made by public opinion — a power to which all must submit in America. The one most important, and without which it would be impossible to travel in such a gregarious way, is a universal deference and civility shown to the women, who may in consequence travel without protection all over the United States without the least chance of annoyance or insult. This deference paid to the sex is highly credit-able to the Americans; it exists from one end of the Union to the other; indeed, in the southern and more lawless states, it is even more chivalric than in the more settled. Let a female be ever so indifferently clad, whatever her appearance may be, still it is sufficient that she is a female; she has the first accommodation, and until she has it, no man will think of himself. But this deference is not only shewn in travelling, but in every instance. An English lady told me that, wishing to be present at the inauguration of Mr. Van Buren, by some mistake, she and her daughters alighted from the carriage at the wrong entrance, and in attempting to force their way through a dense crowd were nearly crushed to death. This was perceived, and the word was given – "Make room for the ladies." The whole crowd, as if by one simultaneous effort, compressed itself to the right and left, locking themselves together to meet the enormous pressure, and made a wide lane, through which they passed with ease and comfort. "It reminded me of the Israelites passing through the Red Sea with the wall of waters on each side of them," observed the lady. "In any other country we must have been crushed to death."

When I was on board one of the steamboats, an American asked one of the ladies to what she would like to be helped. She replied, to some turkey, which was within reach, and off of which a passenger had just cut the wing and transferred it to his own plate. The American who had received the lady's wishes immediately pounced with his fork upon the wing of the turkey and carried it off to the young lady's plate; the only explanation given, "For a lady, sir!" was immediately admitted as sufficient.

◆

Of all travelling, I think that by railroad the most fatiguing, especially in America. After a certain time the constant coughing of the locomotive, the dazzling of the vision from the rapidity with which objects are passed, the sparks and ashes which fly in your face and on your clothes become very annoying; your only consolation is the speed with which you are passing over the ground.

The railroads in America are not so well made as in England, and are therefore more dangerous; but it must be remembered that at present nothing is made in America but to last a certain time; they go to the exact expense considered necessary and no further; they know that in twenty years they will be better able to spend twenty dollars than one now. The great object is to obtain quick returns for the outlay, and, except in a few instances, durability or permanency is not thought of. One great cause of disasters is that the railroads are not fenced on the sides, so as to keep the cattle off them, and it appears as if the cattle who range the wood are very partial to take their naps on the roads, probably from their being drier than the other portions of the soil. It is impossible to say how many cows have been cut into atoms by the trains in America, but the frequent accidents arising from these causes have occasioned the Americans to invent a sort of shovel, attached to the front of the locomotive which takes up a cow, tossing her off right or left. At every fifteen miles of the railroads there are refreshment rooms; the cars stop, all the doors are thrown open, and out rush the passengers like boys out of school, and crowd round the tables to solace themselves with pies, patties, cakes, hard-boiled eggs, ham, custards, and a variety of railroad luxuries, too numerous to mention. The bell rings for departure, and in they all hurry with their hands and mouths full, and off they go again, until the next stopping place induces them to relieve the monotony of the journey by masticating without being hungry.

The Utica railroad is the best in the United States. The general average of speed is from fourteen to sixteen miles an hour; but on the Utica they go much faster. A gentleman narrated to me a singular specimen of the ruling passion which he witnessed on an occasion when the rail-cars were thrown off the road, and nearly one hundred people killed, or injured in a greater or less degree.

On the side of the road lay a man with his leg so severely fractured that the bone had been forced through the skin and projected outside his trousers. Over him hung his wife, with the utmost solicitude, the blood running down from a severe cut received on her head, and kneeling by his side was his sister, who was also much injured. The poor women were lamenting over him, and thinking nothing of their own hurts; and he, it appears, was also thinking nothing about his injury, but only lamenting the delay which would be occasioned by it.

"Oh! my dear, dear Isaac, what can be done with your leg?" exclaimed the wife in the deepest distress.

"What will become of my leg!" cried the man. "What's to become of my business, I should like to know?"

"Oh! dear brother," said the other female, "don't think about your business now; think of getting cured."

"Think of getting cured – I must think how the bills are to be met, and I not there to take them up. They will be presented as sure as I lie here."

"Oh! never mind the bills, dear husband – think of your precious leg."

"Not mind the bills! But I must mind the bills – my credit will be ruined."

"Not when they know what has happened, brother. Oh! dear, dear – that leg, that leg."

"D---n the leg; what's to become of my business?" groaned the man, falling on his back from excess of pain.

Now this was a specimen of true commercial spirit. If this man had not been nailed to the desk, he might have been a hero...

The most general, the most rapid, the most agreeable, and, at the same time, the most dangerous of American travelling is by steamboats...

The American steamboats are very different from ours in appearance, in consequence of the engines being invariably on deck. The decks also are carried out many feet wider on each side than the hull of the vessel, to give space: these additions to the deck are called guards. The engine being on the first deck, there is a second deck for the passengers, state-rooms, and saloons: and above this deck there is another, covered with a white awning. They have something the appearance of two-deckers, and when filled with company, the variety of colors worn by the ladies have a very novel and pleasing effect. The boats which run from New York to Boston, and up the Hudson River to Albany, are very splendid vessels: they have low-pressure engines, are well commanded, and I never heard of any accident of any importance taking place: their engines are also very superior – one on board of the *Narragansett*, with a horizontal stroke, was one of the finest I ever saw. On the Mississippi, Ohio, and their tributary rivers, the high-pressure engine is invariably used: they have tried the low-pressure, but have found that it will not answer, in consequence of the great quantity of mud contained in solution on the waters of the Mississippi, which destroys all the valves and leathers: and this is the principal cause of the many accidents which take place. At the same time it must be remembered that there is a recklessness – an indifference to life – shown throughout all America, which is rather a singular feature, inasmuch as it extends east as well as west. It can only be accounted for by the insatiate pursuit of gain, among a people who consider that time is money, and who are blinded by their eagerness in the race for it, added to that venturous spirit so naturally imbibed in a new country at the commencement of its occupation. It is communicated to the other sex, who appear equally indifferent. The *Moselle* had not been blown up two hours before the other steamboats were crowded with women, who followed their relations on business or pleasure, up and down the river. "Go ahead" is the motto of the country; both sexes join in the cry; and they do go ahead – that's a fact!*…

At present, it certainly is more dangerous to travel one week in America than to cross the Atlantic a dozen times. The number of lives lost in one year by accidents in steamboats, railroads, and coaches was estimated, in a periodical which I read in America, at one thousand seven hundred and fifty!

An excerpt from *A Diary in America with Remarks on Its Institutions*, by Captain Frederick Marryat (London, 1839).

*When the water in the rivers is low, the large steam vessels very often run aground, and are obliged to discharge their cargoes and passengers. At these times, the smaller steamboats ply up and down the rivers to take advantage of these misfortunes by picking up passengers and making most exhorbitant charges for taking them or the goods out, because you must pay them or remain where you are. This species of cruising they themselves designate as "going a-pirating." I will say this for the Americans, that, if a person, who considers that he is not doing wrong, does not do wrong, they are a very honest people.

No Midwestern Industry?

In the following paragraph, Captain Marryat makes a prediction. As you read, think about whether the prediction has come true in the 142 years since he wrote.

As soon as the eastern states are no longer permitted to remain the factors of the western, they must be content to become manufacturing states, and probably will compete with England. The western states, providentially, I may say, are not likely to be manufacturers to any great extent, for they have not water power; the valley of the Mississippi is an alluvial flat, and although the Missouri and Mississippi are swift streams, in general the rivers are sluggish, and at all events, they have not the precipitate falls of water necessary for machinery, and which abound in the northeastern states; indeed, if the western states were to attempt to manufacture, as well as to produce, they would spoil the market for their own produce. Whatever may be the result, whether the eastern states submit quietly to be shorn of their greatness (a change which must take place) or to contest the point until it ends in a separation, this is certain, that the focus of American wealth and power will eventually be firmly established in the free states on the other side of the Allegheny mountains.

Reading Carefully

1. Why does Marryat think the states west of the Alleghenies will never be great manufacturing states?

Thinking It Over

1. Was Marryat right in thinking there were no great waterfalls in the Mid-West?
2. Has any hydroelectric power been developed in the Mid-West? How was this possible if there weren't many natural waterfalls?
3. Did the Mid-West become a great manufacturing area?
4. Marryat made a false assumption. What was it?

An excerpt from **A Diary in America with Remarks on Its Institutions**, by Captain Frederick Marryat London, 1839).

Salt

Captain Marryat went on a trip on the Erie Canal, through New York State. On the way he passed a local industry.

After you pass Syracuse, the country wears a more populous and inviting appearance. Salina is a village built upon a salt spring, which has the greatest flow of water yet known, and this salt spring is the cause of the improved appearance of the country; the banks of the canal for three miles are lined with buildings for the boiling down of the salt water, which is supplied by a double row of wooden pipes. Boats are constantly employed up and down the canal, transporting wood for the supply of the furnaces. It is calculated that two hundred thousand cord of wood are required every year for the present produce; and as they estimate upon an average about sixty cord of wood per acre in these parts, those salt works are the means of yearly clearing away upwards of three thousand acres of land. Two million of bushels of salt are boiled down every year; it is packed in barrels, and transported by the canals and lakes to Canada, Michigan, Chicago, and the far west. When we reflect upon the number of people employed in the manufactories, and in cutting wood, and making barrels, and engaged on the lakes and canals in transporting the produce so many thousand miles, we must admire the spring to industry which has been created by this little, but bounteous, spring presented by nature.

Reading Carefully

1. How did the people get the salt from salt water?
2. Why does Marryat say this industry caused "improved appearance of the countryside?" What does he mean by "clearing away?"
3. How was the salt water carried from the spring to the place where it was boiled down?
4. How did the canal help make this industry possible?

Thinking It Over

1. How many cords of wood were used to get one bushel of salt?
2. One cord of air-dry hardwood weighs about 3,500 pounds and yields 20 million Btu when burnt. A gallon of fuel oil yields around 150,000 Btu. How many gallons of fuel oil would be equivalent to the wood burned in this industry?
3. What was salt used for in 1837? How do we do those things today? What changes in the use of energy has that made?

An excerpt from **A Diary in America with Remarks on Its Institutions**, by Captain Frederick Marryat (London, 1839).

Notes

The End of Steamboating Days

From 1856 to 1861, Samuel Clemens was a pilot of steamboats on the Mississippi River. Later, as Mark Twain, he became one of the greatest American writers. In 1882, 21 years after leaving the river, Mark Twain returned to visit the places he had worked. This is what he found at Saint Louis.

The further we drove in our inspection-tour, the more sensibly I realized how the city had grown since I had seen it last; changes in detail became steadily more apparent and frequent than at first, too: changes uniformly evidencing progress, energy, prosperity.

But the change of changes was on the 'levee*.' This time, a departure from the rule. Half a dozen sound-asleep steamboats where I used to see a solid mile of wide-awake ones! This was melancholy, this was woful. The absence of the pervading and jocund* steamboatman from the billiard-saloon was explained. He was absent because he is no more. His occupation is gone, his power has passed away, he is absorbed into the common herd, he grinds at the mill, a shorn Samson* and inconspicuous. Half a dozen lifeless steamboats, a mile of empty wharves, a negro fatigued with whiskey stretched asleep, in a wide and soundless vacancy, where the serried* hosts of commerce used to contend![1] Here was desolation, indeed.

> 'The old, old sea, as one in tears,
> Comes murmuring, with foamy lips,
> And knocking at the vacant piers,
> Calls for his long-lost multitude of
> ships.'

The towboat and the railroad had done their work, and done it well and completely. The mighty bridge, stretching along over our heads, had done its share in the slaughter and spoliation. Remains of former steamboatmen told me, with wan satisfaction, that the bridge doesn't pay. Still, it can be no sufficient compensation to a corpse, to know that the dynamite that laid him out was not of as good quality as it had been supposed to be.

The pavements along the river front were bad: the sidewalks were rather out of repair; there was a rich abundance of mud. All this was familiar and satisfying; but the ancient armies of drays†, and struggling throngs of men, and mountains of freight, were gone; and Sabbath reigned in their stead. The immemorial mile of cheap foul doggeries† remained, but business was dull with them; the multitudes of poison-swilling Irishmen had departed, and in their places were a few scattering handfuls of ragged negroes, some drinking, some drunk, some nodding, others asleep. St. Louis is a great and prosperous and advancing city; but the river-edge of it seems dead past resurrection.

Mississippi steamboating was born about 1812; at the end of thirty years, it had grown to mighty proportions; and in less than thirty more, it was dead! A strangely short life for so majestic a creature. Of course it is not absolutely dead, neither is a crippled octogenarian who could once jump twenty-two feet on level ground; but as contrasted with what it was in its prime vigour, Mississippi steamboating may be called dead.

*the raised banks of the river

†wagons used to haul goods

*mirthful

†cheap saloons

*The Bible story is in Judges 16:4-21.

*crowded, pressed together

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[1] Capt. Marryat, writing forty-five years ago, says: 'St. Louis has 20,000 inhabitants. The river abreast of the town is crowded with steamboats, lying in two or three tiers.'

It killed the old-fashioned keel-boating, by reducing the freight-trip to New Orleans to less than a week. The railroads have killed the steamboat passenger traffic by doing in two or three days what the steamboats consumed a week in doing; and the towing-fleets have killed the through-freight traffic by dragging six or seven steamerloads of stuff down the river at a time, at an expense so trivial that steamboat competition was out of the question.

Freight and passenger way-traffic remains to the steamers. This is in the hands — along the two thousand miles of river between St. Paul and New Orleans — of two or three close corporations well fortified with capital; and by able and thoroughly business-like management and system, these make a sufficiency of money out of what is left of the once prodigious steamboating industry. I suppose that St. Louis and New Orleans have not suffered materially by the change, but alas for the wood-yard man!

He used to fringe the river all the way; his close-ranked merchandise stretched from the one city to the other, along the banks, and he sold uncountable cords of it every year for cash on the nail; but all the scattering boats that are left burn coal now, and the seldomest spectacle on the Mississippi today is a wood-pile. Where now is the once wood-yard man?

Reading Carefully

1. What new forms of transportation had taken the place of the steamboat?
2. What was the name of the job of the person who sold energy to the steamboats?
3. Why did people prefer the steamboat to the keel-boat?
4. Why did people prefer the railroad to the steamboat?
5. For carrying freight, why did people prefer the towing-fleet to the steamboats?
6. What fuel did the steamboats burn when Mark Twain was a pilot? What fuel does he say the few remaining boats are burning?

Thinking It Over

1. Can you think of any occupations today that might be gone or sharply reduced by an energy transition, the way the woodyard man's was? What would they be, and why do you think they might change.
2. Mark Twain doesn't specifically mention any new jobs, but the changes he describes imply that many different new jobs were created. How many can you list?
3. What do you think Twain's feelings were when he saw the Saint Louis waterfront? Why did he feel that way? Why does a person find some changes sad?

Finding out More Information

1. What was "old-fashioned keel-boating"? What was its source of energy?
2. What products did boats carry on the Mississippi in 1810 . . . in 1858? . . . in 1881?
3. A hundred years have passed since Twain's visit to Saint Louis. Is there still river traffic on the Mississippi? What is carried? What source of energy is used?

Pioneers on the Great Plains 1

Objectives

The purpose of this lesson is to focus the students' attention on the time and place we will be studying, and introduce the primary source materials to be used.

Teacher Background

In the closing decades of the 1800s the daily life of the average American began to be affected greatly by the use of powered machinery and fossil fuels. The transition from millenia of muscle power and wood had begun.

In this set of lessons, we will try to help students feel what it was like to live in those times, and to compare how people did things in those days with how we do them now.

In the first section, we use as a backbone the series of autobiographical **Little House on the Prairie** books written by Laura-Ingalls Wilder. These books are well within the reading ability of seventh-graders, and even many fourth-graders; yet they are masterpieces that hold the attention of adults. Because the activities suggest additional readings from the books, we recommend that you make multiple copies available for students in the classroom. The whole set is available boxed in paperbound for $19.95.

The individual volumes with greatest usefulness for this project are **Little House on the Prairie, Little Town on the Prairie,** and **Farmer Boy;** they typically cost about $2.00 each. The paperbound (Torch edition) and hardbound editions have the same page numbers.

Materials Needed

wall map	of United States.
reading	**By the Hearth.**
Wilder Books	
reading	**A Sudden Storm.**

Identify the Time and Place

Use the wall map to show the United States. Discuss how people moved from the Atlantic seaboard westward.

Ask, what did these people do for a living? What were they looking for?

Discuss the different kinds of land the pioneers found as they moved westward — the Appalachian barrier, then moving on to the Great Plains.

Ask, when was the first transcontinental railroad completed? Locate its route on the map. This connected the eastern states with California. But the Great Plains were not yet settled. They did not appear as fertile to farmers as the woodlands they were used to. These areas were not really settled until after the Civil War.

Introducing Laura Ingalls Wilder

Tell the class about the little girl who went with her family from one state to another. Trace their route on the wall map, using the map below.

Tell the class that this girl became an author and wrote a series of books which a generation of readers has recognized as classics. The characters of these books were used to make a television series, Little House on the Prairie — but you may want to point out that what happens in the television series is not exactly the same as what happens in the books.

You may also wish to explore with the students the problem of the veracity of eyewitness reports. We know that in some respects Laura's account is inaccurate. We know this because we can compare her version with the versions of other eyewitnesses who made records. Similarly in a trial, different witnesses to a car accident may remember it differently, but by comparing these versions the jury reaches a decision about what happened. The historian goes through a similar process.

We are fortunate that Laura has lovingly described the farmers' and pioneers' chores in such detail, for these descriptions give us a good picture of how energy was used in those days.

The First Reading

Pass out the reading, **By the Hearth.**

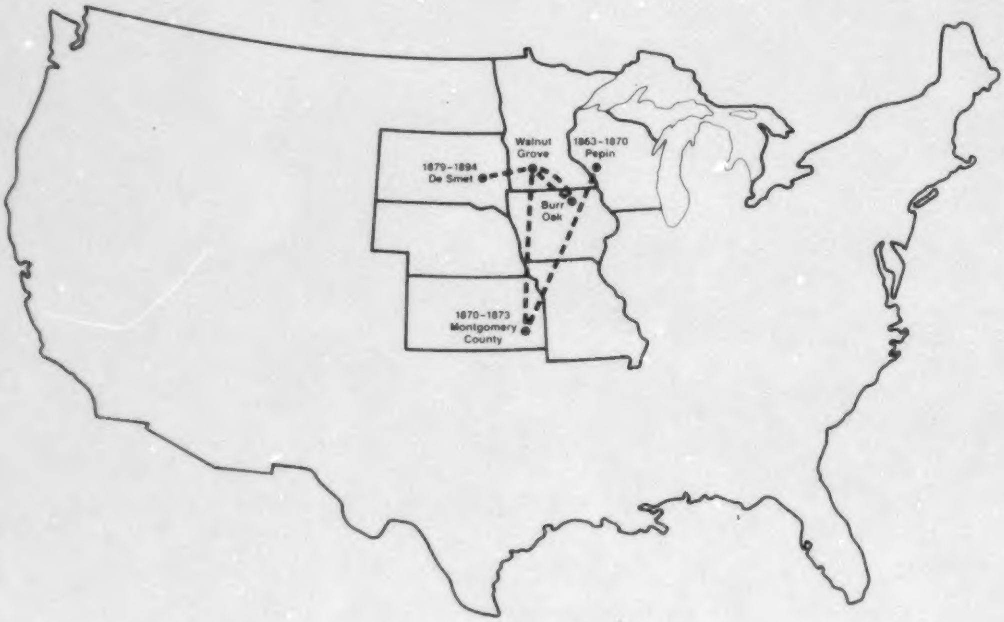
Allow time for students to read the paragraphs silently to themselves. Let students who finish early prepare written answers to the "Thinking It Over" questions.

Discussion

Call on students for answers to the recall questions in "Reading Carefully." Then discuss the second set of questions. Try to focus the students' attention on people's need for certain things to live.

Homework Assignment

Assign the reading, **A Sudden Storm** and the associated questions for homework.



By the Hearth

About a hundred years ago, pioneering farmers were moving into the prairies of the middle United States. One of these families was the Ingalls, who moved from Wisconsin to Minnesota, to Iowa, to Missouri, to Kansas, back to Minnesota, back to Iowa, and finally to South Dakota. The second oldest of the Ingalls' children was Laura. When Laura grew up, she wrote eight books describing her family's adventures.

Laura's true stories have become some of the best-loved books ever written by an American. You may have seen the television series, **Little House on the Prairie**, based on the characters in the books. But the books themselves are even more interesting, and are one of the best pictures we have of life in pioneer American in the 1880's.

Then the fire was shining on the hearth, the cold and the dark and the wild beasts were all shut out, and Jack the brindle bulldog and Black Susan the cat lay blinking at the flames in the fireplace.

Ma sat in her rocking chair, sewing by the light of the lamp on the table. The lamp was bright and shiny. There was salt in the bottom of its glass bowl with the kerosene, to keep the kerosene from exploding, and there were bits of red flannel among the salt to make it pretty. It was pretty.

Laura loved to look at the lamp, with its glass chimney so clean and sparkling, its yellow flame burning so steadily, and its bowl of clear kerosene colored red by the bits of flannel. She loved to look at the fire in the fireplace, flickering and changing all the time, burning yellow and red and sometimes green above the logs, and hovering blue over the golden and ruby coals.

And then, Pa told stories.

Reading Carefully

1. What animals were allowed inside the house?
2. What was Ma doing?
3. How was the house heated?
4. How was the house lit?

Thinking It Over

1. Would you like to live the way Laura did?
2. What do people need to live? to feel safe and comfortable?
3. Two energy sources were being used in the Ingalls' home. What were they? How do you think the Ingalls got them?
4. What good did the family get out of consuming this energy?

Finding out More Information

1. Where does the word "kerosene" come from? What does it mean today? Did it always mean that?

Text excerpt from **LITTLE HOUSE IN THE BIG WOODS** by Laura Ingalls Wilder. Copyright, 1932, as to text, by Laura Ingalls Wilder. Renewed 1959 by Roger L. MacBride. By permission of Harper & Row, Publishers, Inc.

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A Sudden Storm

Mary was angry and so was Laura. They would have gone on quarreling, but suddenly there was no sunshine. They ran to look through the bedroom window.

A dark cloud with a fleecy white underside was rolling fast from the north-west.

Mary and Laura looked out the front window. Surely it was time for Pa and Ma to come, but they were nowhere in sight.

"Maybe it's a blizzard," said Mary.

"Like Pa told us about," said Laura.

They looked at each other through the grey air. They were thinking of those children who froze stark stiff.

"The woodbox is empty," said Laura.

Mary grabbed her. "You can't," said Mary. "Ma told us to stay in the house if it stormed." Laura jerked away and Mary said, "Besides, Jack won't let you."

"We've got to bring in wood before the storm gets here," Laura told her. "Hurry!"

They could hear a strange sound in the wind, like a far-away screaming. They put on their shawls and pinned them under their chins with their large shawl-pins. They put on their mittens.

Laura was ready first. She told Jack, "We've got to bring in wood, Jack." He seemed to understand. He went out with her and stayed close at her heels. The wind was colder than icicles. Laura ran to the woodpile, piled up a big armful of wood, and ran back, with Jack behind her. She could not open the door while she held the wood. Mary opened it for her.

Then they did not know what to do. The cloud was coming swiftly, and they must both bring in wood before the storm got there. They could not open the door when their arms were full of wood. They could not leave the door open and let the cold come in.

"I tan open the door," said Carrie.

"You can't," Mary said.

"I tan, too!" said Carrie, and she reached up both hands and turned the door knob. She could do it! Carrie was big enough to open the door.

Laura and Mary hurried fast, bringing in wood. Carrie opened the door when they came to it, and shut it behind them. Mary could carry larger armfuls, but Laura was quicker.

Text excerpt from **ON THE BANKS OF PLUM CREEK** by Laura Ingalls Wilder. Copyright, 1937, as to text, by Harper & Row, Publishers, Inc. Renewed 1965 by Roger L. MacBride. By permission of Harper & Row, Publishers, Inc.

They filled the woodbox before it began to snow. The snow came suddenly with a whirling blast, and it was small hard grains like sand. It stung Laura's face where it struck. When Carrie opened the door, it swirled into the house in a white cloud.

Laura and Mary forgot that Ma had told them to stay in the house when it stormed. They forgot everything but bringing in wood. They ran frantically back and forth, bringing each time all the wood they could stagger under.

They piled wood around the woodbox and around the stove. They piled it against the wall. They made the piles higher, and bigger.

Bang! they banged the door. They ran to the woodpile. Clop-clop-clop they stacked the wood on their arms. They ran to the door. Bump! it went open, and bang! they back-bumped it shut, and thumpity-thud-thump! they flung down the wood and ran back, outdoors, to the woodpile, and panting back again.

They could hardly see the woodpile in the swirling whiteness. Snow was driven all in among the wood. They could hardly see the house, and Jack was a dark blob hurrying beside them. The hard snow scoured their faces. Laura's arms ached and her chest panted and all the time she thought, "Oh, where is Pa? Where is Ma? and she felt "Hurry! Hurry!" and she heard the wind screeching.

The woodpile was gone. Mary took a few sticks and Laura took a few sticks and there were no more. They ran to the door together, and Laura opened it and Jack bounded in. Carrie was at the front window, clapping her hands and squealing. Laura dropped her sticks of wood and turned just in time to see Pa and Ma burst, running, out of the whirling whiteness of snow.

Pa was holding Ma's hand and pulling to help her run. They burst into the house and slammed the door and stood panting, covered with snow. No one said anything while Pa and Ma looked at Laura and Mary, who stood all snowy in shawls and mittens.

At last Mary said in a small voice, "We did go out in the storm, Ma. We forgot."

Laura's head bowed down and she said, "We didn't want to burn up the furniture, Pa, and freeze stark stiff."

"Well, I'll be darned!" said Pa. "If they didn't move the whole woodpile in. All the wood I cut to last a couple of weeks."

There, piled up in the house, was the whole woodpile. Melted snow was leaking out of it and spreading in puddles. A wet path went to the door, where snow lay unmelted.

Then Pa's great laugh rang out, and Ma's gentle smile shone warm on Mary and Laura. They knew they were forgiven for disobeying, because they had been wise to bring in wood, though perhaps not quite so much wood.

Reading Carefully

1. What did the Ingalls family use wood for?
2. What did Laura and Mary do that Ma and Pa had told them not to do? How did they feel about disobeying their parents?
3. We learn what people we know are like by seeing the way they act. Laura and Mary gave Ma and Pa different excuses for going outside. If this was all you knew about the girls, how would you describe their characters?
4. Why did Laura and Mary bring the wood into the house?
5. How did they know a blizzard was coming?
6. Words that sound like a sound they describe are called onomatopoeic words. They can add excitement when something is happening. Make a list of the onomatopoeic words in this story. In what part of the story are they used?

Thinking It Over

1. In your house, what takes the place of the wood the Ingalls used?
2. How does your family get ready for a storm or for winter?
3. Do you use more energy in your house when the weather is very cold? How do you know? What do you use the energy for?
4. What do you think the Ingalls family had to do to get fuel? What does your family have to do?
5. Tell about the time in your life when you were coldest.

Finding out More Information

1. Read Chapter 4, "October Blizzard," of **The Long Winter** by Laura Ingalls Wilder. How were the beans like the firewood? How were the walls of the house like the quilts?

Candlemaking

The end of butchering-time was candlemaking.

Mother scrubbed the big lard-kettles and filled them with bits of beef fat. Beef fat doesn't make lard: it melts into tallow. While it was melting, Almanzo helped string the candle-molds.

A candle-mold was two rows of tin tubes, fastened together and standing straight up on six feet. There were twelve tubes in a mold. They were open at the top, but tapered to a point at the bottom, and in each point there was a tiny hole.

Mother cut a length of candle-wicking for each tube. She doubled the wicking across a small stick, and twisted it into a cord. She licked her thumb and finger, and rolled the end of the cord into a sharp point. When she had six cords on the stick, she dropped them into six tubes, and the stick lay on top of the tubes. The points of the cords came through the tiny holes in the points of the tubes, and Almanzo pulled each one tight, and held it tight by sticking a raw potato ont he tube's sharp point.

When every tube had its wick, held straight and tight down its middle, Mother carefully poured the hot tallow. She filled every tube to the top. Then Almanzo set the mold outdoors to cool.

When the tallow was hard, he brought the mold in. He pulled off the potatoes. Mother dipped the whole mold quickly into boiling water, and lifted the sticks. Six candles came up on each stick.

Then Almanzo cut them off the stick. He trimmed the ends of wicking off the flat ends, and he left just enough wicking to light, on each pointed end. And he piled the smooth, straight candles in waxy-white piles.

All one day Almanzo helped Mother make candles. That night they had made enough candles to last till butchering-time next year.

Reading Carefully

1. What were the candles made out of? Why did candle making take place at the end of butchering-time?
2. What tools would you have to buy to make candles the way Mrs. Wilder did?
3. What were the potatoes used for?
4. When the candles had hardened, how did Mrs. Wilder get them out of the mold?

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Thinking It Over

1. Have you ever made candles? Tell about it.
2. Have you ever used candles in your household? When and why? In what ways was it better than electric light? In what ways worse? Were there any things you usually do by electric light that you couldn't do by candlelight?
3. How long did it take to make enough candles for a year? How many people helped? How many person days of labor does it take to provide your family with artificial light for a year? Do you think your family uses more artificial light than the Wilders did? Why?

Finding out More Information

1. Make some candles.
2. How many different non-electric ways of making light can be bought in your community? Compare their costs and advantages and disadvantages.

Notes

Icecutting

In this story, Almonzo goes with his father and brother to cut ice from a frozen lake. Lazy John and French Joe are two men who occasionally work for Almonzo's father.

He trudged with the others across the ice to the middle of the pond. A sharp wind blew there, driving wisps of snow before it. Above the deep water the ice was smooth and dark, swept almost bare of snow. Almanzo watched while Joe and John chopped a big, three-cornered hole in it. They lifted out the broken pieces of ice and carried them away, leaving the hole full of open water.

"She's about twenty inches thick," Lazy John said.

"Then saw the ice twenty inches," said Father.

Lazy John and French Joe knelt at the edge of the hole. They lowered their cross-cut saws into the water and began to saw. Nobody pulled the ends of the saws under water.

Side by side, they sawed two straight cracks through the ice, twenty inches apart, and twenty feet long. Then with the ax John broke the ice across, and a slab twenty inches wide, twenty inches thick, and twenty feet long rose a little and floated free.

With a pole John pushed the slab toward the three-cornered hole, and as the end was thrust out, crackling the thin ice freezing on the water, Joe sawed off twenth-inch lengths of it. Father picked up the cubes with the big iron ice-tongs, and loaded them on the bobsled.

Almanzo ran to the edge of the hole, watching the saw. Suddenly, right on the very edge, he slipped.

He felt himself falling headlong into the dark water. His hands couldn't catch hold of anything. He knew he would sink and be drawn under the solid ice. The swift current would pull him under the ice, where noboby could find him. He'd drown, held down by the ice in the dark.

French Joe grabbed him just in time. He heard a shout and felt a rough hand jerk him by one leg, he felt a terrific crash, and then he was lying on his stomach on the good, solid ice. He got up on his feet. Father was coming, running.

Father stood over him, big and terrible.

"You ought to have the worst whipping of your life," Father said.

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"Yes, Father," Almanzo whispered. He knew it. He knew he should have been more careful. A boy nine years old is too big to do foolish things because he doesn't stop to think. Almanzo knew that, and felt ashamed. He shrank up small inside his clothes and his legs shivered, afraid of the whipping. Father's whippings hurt. But he knew he deserved to be whipped. The whip was on the bobsled.

"I won't thrash you this time," Father decided. "But see to it you stay away from that edge."

"Yes, Father," Almanzo whispered. He went away from the hole, and did not go near it again.

Father finished loading the bobsled. Then he spread the laprobes on top of the ice, and Almanzo rode on them with Father and Royal, back to the ice-house near the barns.

The ice-house was built of boards with wide cracks between. It was set high from the ground on wooden blocks, and looked like a big cage. Only the floor and the roof were solid. On the floor was a huge mound of sawdust, which Father had hauled from the lumber-mill.

With a shovel Father spread the sawdust three inches thick on the floor. On this he laid the cubes of ice, three inches apart. Then he drove back to the pond, and Almanzo went to work with Royal in the ice-house.

They filled every crack between the cubes with sawdust, and tamped it down tightly with sticks. Then they shoveled the whole mound of sawdust on top of the ice, in a corner, and where it had been they covered the floor with cubes of ice and packed them in sawdust. Then they covered it all with sawdust three inches thick.

They worked as fast as they could, but before they finished, Father came with another load of ice. He laid down another layer of ice cubes three inches apart, and drove away, leaving them to fill every crevice tightly with sawdust, and spread sawdust over the top, and shovel the rest of the mound of sawdust up again.

They worked so hard that the exercise kept them warm, but long before noon Almanzo was hungrier than wolves. He couldn't stop work long enough to run into the house for a doughnut. All of his middle was hollow, with a gnawing inside it.

He knelt on the ice, pushing sawdust into the cracks with his mittened hands, and pounding it down with a stick as fast as he could, and he asked Royal,

"What would you like best to eat?"

They talked about spareribs, and turkeys with dressing, and baked beans, and crackling cornbread, and other good things. But Almanzo said that what he liked most in the world was fried apples'n'onions.

When, at last, they went in to dinner, there on the table was a big dish of them! Mother knew what he liked best, and she had cooked it for him.

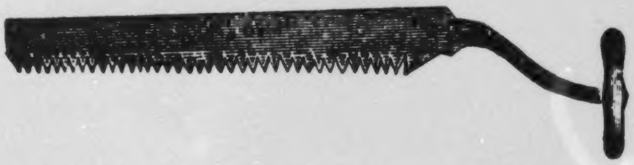
Almanzo ate four large helpings of apples'n'onions fried together. He ate roast beef and brown gravy, and mashed potatoes and creamed carrots and boiled turnips, and countless slices of buttered bread with crab-apple jelly.

"It takes a great deal to feed a growing boy," Mother said. And she put a thick slice of birds'-nest pudding on his bare plate, and handed him the pitcher of sweetened cream speckled with nutmeg.

Almanzo poured the heavy cream over the apples nested in the fluffy crust. The syrupy brown juice curled up around the edges of the cream. Almanzo took up his spoon and and ate every bit.

Then until chore-time he and Royal worked in the ice-house. All next day they worked, and all the next day. Just at dusk on the third day, Father helped them spread the last layer of sawdust over the topmost cubes of ice, in the peak of the ice-house roof. And that job was done.

Buried in sawdust, the blocks of ice would not melt in the hottest summer weather. One at a time they would be dug out, and Mother would make ice-cream and lemonade and cold egg-nog.



40201—Pond Ice Saws, set and sharpened, tapered from 7 inches to 5 inches at the point: complete with tiller handle, 4 feet long. Each $2.40
4½ feet long, each 2.70
5 feet long, each 3 00

Reading Carefully

1. How did they get the ice out of the lake?
2. How big was each block of ice?
3. How many different tools are mentioned in the story? Make a list.
4. What made Father angry? Did Almanzo think Father was right to be angry?
5. How did the Wilders carry the ice from the pond to their farm? Where did the energy to transport the ice come from?
6. What did the Wilders use as an insulator when they stored the ice? Where did they get it? What would have happened if they hadn't used an insulator? How thick a layer did they use?
7. What did the Wilders use the ice for?

Thinking It Over

1. Did you ever carry ice or other cold things to a picnic? How did you store them to keep them from melting?
2. If you were going to build an ice house today, what would you use as an insulator? How would you store the ice?
3. How many people for how many days were needed to provide the Wilder family with ice for a year? How many person-days of your family's labor are needed each year to provide your family with ice?
4. When do you use cold in your life? Would you miss it if you couldn't get it?

Talking About Horses

In **Farmer Boy**, Laura Wilder describes a visit Mr. Wilder and Almanzo make to the County Fair. Father and son are both very interested in seeing the horses.

Beyond them were large, speckled gray horses. Their haunches were round and hard, their necks were thick and their legs were heavy. Long, bushy hair hid their big feet. Their heads were massive, their eyes quiet and kind. Almanzo had never seen anything like them.

Father said they were Belgians. They came from a country called Belgium, in Europe. Belgium was next to France, and the French had brought such horses in ships to Canada. Now Belgian horses were coming from Canada into the United States. Father admired them very much. He said,

"Look at that muscle! They'd pull a barn, if hitched to it."

Almanzo asked him:

"What's the good of a horse that can pull a barn? We don't want to pull a barn. A Morgan* has muscle enough to pull a wagon, and he's fast enough to pull a buggy, too."

"You're right, son!" Father said. He looked regretfully at the big horses, and shook his head. "It would be a waste to feed all that muscle, and we've got no use for it. You're right."

*A Morgan is a kind of horse.

Reading Carefully

1. What did Father admire about the Belgians?
2. Why did Almanzo think the Belgians were not what they needed?
3. Father says "it would be a waste to feed all that muscle." What does he mean?

Thinking It Over

1. Would it have taken more energy for Mr. Wilder to use Belgians than to use Morgans? Why? What form would the energy be in? Would Mr. Wilder have gotten more useful work out of the Belgians?
2. What jobs might a Belgian be good for that you couldn't use a Morgan for?
3. In the 1880s, where did the energy to farm come from?
4. Rewrite this story as if it were 1980 and a boy and his father are in an automobile showroom looking at automobiles or trucks.
5. In a car, do you have to "feed all that muscle" as you do with a horse?

Finding out More Information

1. Read the sections on the Morgan, the Belgian, the Quarterhorse, and the Shire in **An Album of Horses,** by Marguerite Henry. What was each of these kinds of horse good for?
2. Read **Justin Morgan Had a Horse,** by Marguerite Henry, or **The Horse in America,** by Olive W. Burt.

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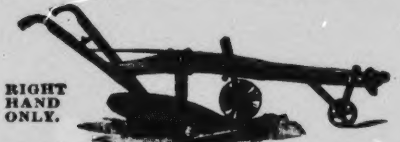
A New Plow

Pa had a new plow, a breaking plow. It was wonderful for breaking the prairie sod. It had a sharp-edged wheel, called a rolling coulter, that ran rolling and cutting through the sod ahead of the plowshare. The sharp steel plowshare followed it, slicing underneath the matted grass roots, and the moldboard lifted the long, straight-edged strip of sod and turned it upside down. The strip of sod was exactly twelve inches wide, and as straight as if it had been cut by hand.

They were all so happy about that new plow. Now, after a whole day's work, Sam and David gaily lay down and rolled, and pricked their ears and looked about the prairie before they fell to cropping grass. They were not being worn down, sad and gaunt, by breaking sod that spring. And at supper, Pa was not too tired to joke.

"By jingo, that plow can handle the work by itself," he said. "With all these new inventions nowadays, there's no use for a man's muscle. One of these nights that plow'll take a notion to keep on going, and we'll look out in the morning and see that it's turned over an acre or two after the team and I quit for the night."

Acme Prairie Breaking Plows.



Our Prairie Breaker combines many desirable qualities. Its construction is light and strong; the beam is adjustable; the shape is as near perfection as can be made; it turns a flat furrow with great ease and without breaking the sod; it is made with solid bar share, which is far superior to those formerly used on breakers. Shares are made to duplicate on all breakers. The many desirable qualities of this plow cannot help but bring it into great favor. **Shipped direct from factory in Northern Illinois.**

No. 32R249 Size, 12 inches; weight, 100 pounds; complete with rolling coulter, gauge wheel and extra share. Price..**$9.85**

Reading Carefully

1. Why was the plow called a "breaking plow"?
2. Why were the girls happy about it? Why were Sam and David happy about it?

Thinking It Over

1. What benefit did Pa get from the new plow? What extra costs did Pa incur to get these benefits?
2. How have machines changed the relative importance of brain and muscle?

Text excerpt from **LITTLE TOWN ON THE PRAIRIE** by Laura Ingalls Wilder. Copyright, 1941, as to text, by Laura Ingalls Wilder. Renewed 1969 by Roger L. MacBride. By permission of Harper & Row, Publishers, Inc.

Notes

A Sewing Machine

"There's no flies on Clancy," said Pa. "He's got a machine to sew the shirts."

Ma was interested. "A sewing machine. Is it like that picture we saw in the "Inter-Ocean"? How does it work?

"About like I figured out it would," Pa answered. "You work the pedal with your feet, and that turns the wheel and works the needle up and down. There's a little contraption underneath the needle that's wound full of thread, too. Clancy was showing some of us. It goes like greased lightning, and makes as neat a seam as you'd want to see."

I wonder how much it costs,"said Ma.

"Way too much for ordinary folks," said Pa. "But Clancy looks on it as an investment, he'll get his money back in profits."

"Yes, of course, " Ma said. Laura knew she was thinking how much work such a machine would save, but even if they could afford it, it would be foolish to buy one for family sewing. "Does he expect Laura to learn how to run it?"

Laura was alarmed. She could not be responsible for some accident to such a costly machine.

Reading Carefully

1. Where did the energy to run Clancy's sewing machine come from?

2. Why wouldn't "ordinary folks" want one of the new machines, but Clancy would?

3. How did Mrs. Ingalls, way out on the frontier, know such a thing existed when she'd never seen one?

Thinking It Over

1. Today many families have sewing machines; they are not so expensive that only businesses can buy them. What made this possible?

2. For you, what takes the place of Ma's "Inter-Ocean?" Do you think you get more or less news than Ma did about things happening outside your everyday experiences? What has made this possible?

Text excerpt from **LITTLE HOUSE IN THE BIG WOODS** by Laura Ingalls Wilder. Copyright, 1932, as to text, by Laura Ingalls Wilder. Renewed 1959 by Roger L. MacBride. By permission of Harper & Row, Publishers, Inc.

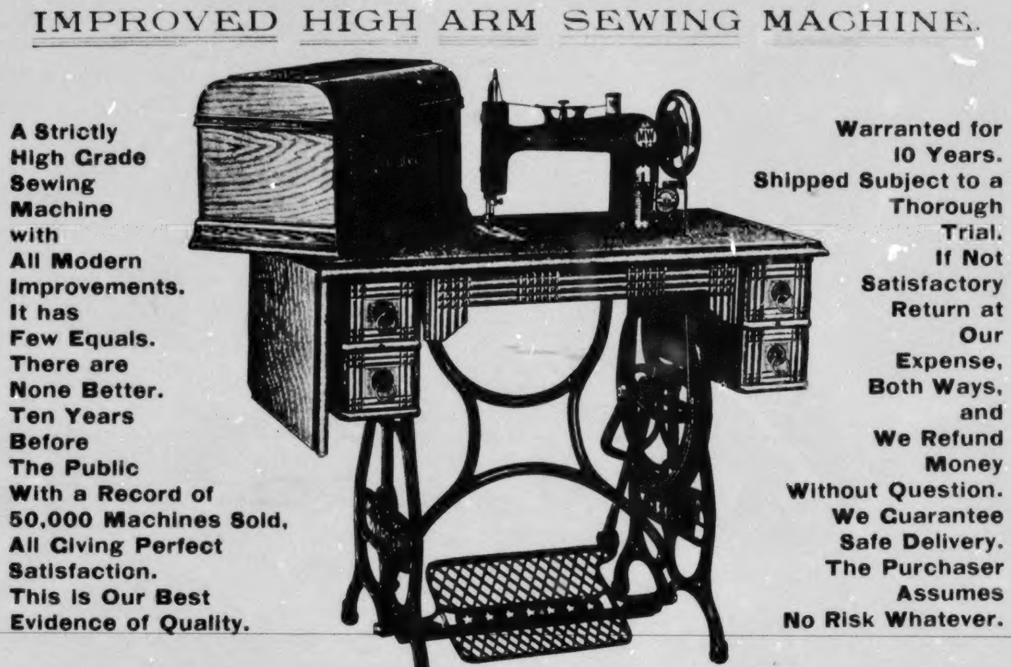
Finding out More Information

1. Are foot-operated sewing machines still made? Who buys them? Where? Why?

2. Learn how to sew a straight seam on a sewing machine. Is it easier to learn to operate a sewing machine or to learn how to make an equally good seam by hand?

3. Read pages 96-107 of **The Shores of Silver Lake**. These describe how the railroad men made the "grade" or bed that the railroad tracks were laid on. Then read, in **Little Town on the Prairie,** the description of when Laura went to work for the man who bought the sewing machine. What was similar about the sewing and the making of the grade?

4. Can you think of anything that only businesses think of owning today, but that families might own in the future? Explain why you think this will happen.



IMPROVED HIGH ARM SEWING MACHINE.

A Strictly High Grade Sewing Machine with All Modern Improvements. It has Few Equals. There are None Better. Ten Years Before The Public With a Record of 50,000 Machines Sold, All Giving Perfect Satisfaction. This is Our Best Evidence of Quality.

Warranted for 10 Years. Shipped Subject to a Thorough Trial. If Not Satisfactory Return at Our Expense, Both Ways, and We Refund Money Without Question. We Guarantee Safe Delivery. The Purchaser Assumes No Risk Whatever.

The above cut is an exact representation of Montgomery Ward & Co.'s High Arm Sewing Machine Nos. 5 and 5½.

OUR PRICES:

No. 5—Five drawers, as shown in cut, walnut woodwork $19.50

No. 5½—Five drawers, as shown in cut, oak woodwork, very popular $19.70

No. 6—Seven drawers, three on each side and center drawer, walnut woodwork $20.50

No. 6½—Seven drawers, three on each side and center drawer, oak woodwork $20.80

ABOVE STYLES, CRATED FOR SHIPMENT, WEIGH ABOUT 120 POUNDS EACH.

People vs Machines?

Why This Sequence of Lessons?

Much of the increase in the use of energy in the U.S. has been due to the increasing use of powered machinery. The use of machinery has increased the productivity of human labor, but by that very fact has also eliminated jobs (of course, often creating other jobs, and often lowering the price of the goods produced). Thus mechanization presents a continuing social dilemma. Comparing the impact of mechnization in different historical periods and in different societies gives students some perspective on this problem, and also throws some light on the origins of Americans' generally positive attitude toward technical innovation.

Objectives

As a result of these lessons, students will be able to:

Give examples of how the use of power-driver machinery can eliminate jobs

Give examples of how the introduction of power-driven machinery can reduce the cost of production

Relate the impact of mechanization in the U.S. in the late 1800s to the availability of other opportunities for workers

Materials Needed

reading **Mr. Ingalls Threshes,** one per student

reading **Mr. Wilder Threshes,** one per student

reading **Rice Threshers in Indonesia,** one per student

reading **Tomato-Picker,** one per student

CONDUCTING THE LESSON

Ingalls and Wilder on Threshing Machines

Ask the class to read the two threshing readings. Be sure students read Ingalls first. If time permits, you may wish to assign one reading per day, with class discussion of the "Reading Carefully" questions.

If you have come to this lesson from the Laura Ingalls Wilder readings on the plow and the sewing machine, raise the general topic of mechanization. What is it? How are the plow, the sewing machine, and the threshing machine alike? Why do people mechanize their work?

Mr. Wilder and Mr. Ingalls had very different attitudes about using a machine to thresh their wheat. Ask students to find and read aloud the sentences that best describe the feelings of the two men. (Bottom of 2nd column, page 6-54; top of 2nd column, page 6-56)

Take a show of hands. How many students agree with Mr. Wilder? How many with Mr. Ingalls? Usually, most students will agree with Mr. Ingalls.

Comparing the American Experience with That of Another Culture

Ask the students to read **Rice Threshing in Indonesia.** Hold a class discussion following the pattern of questions at the end of the reading. Be sure to bring out the difference in the opportunities available to Mr. Ingalls and the Indonesian women. Can the Indonesians homestead new land? Can they find work in growing urban industries?

In proportion to its natural resources, America historically has been labor-short. Many observers have claimed that Americans on the whole are more eager to adopt new machines than almost any other group on earth. Has the experience Americans have had with new technology been good or bad? Why? Do Americans always embrace new technology?

Comparing the Past and Present

Now ask the students to read **Tomato-Pickers.** You may wish them to answer, as homework, the "Reading Carefully" and "Thinking It Over" questions following the reading. Please review these questions yourself.

How is the situation described in **Tomato-Pickers** like the one Mr. Ingalls and Mr. Wilder were in? How is it different? How is it like the one the Indonesian women were in? Ask students what they think. Is mechanization to be encouraged? Require students to support their opinions with examples.

You may wish to shift focus from agriculture to industry, especially if your students have trouble relating to farming. Consider discussing the use of robots in factories. For example, robots spray-paint automobiles more consistently than people do, and are cheaper in the long run. They can be run in an environment in which people could not survive (due to fumes) but which improves the painting process. Is replacing workers with these machines a good thing?

Mr. Ingalls Threshes

In this passage from **Little House in the Big Woods**, Laura Ingalls Wilder describes how a new machine came to thresh the wheat. Threshing separates the kernels of wheat from the wheat stalk and removes the chaff, a hull around each kernel. The wheat berries that are left are then ready to be ground into flour.

One frosty morning, a machine came up the road. Four horses were pulling it, and two men were on it. The horses hauled it up into the field where Pa and Uncle Henry and Grandpa and Mr. Peterson had stacked their wheat.

Two more men drove after it another, smaller machine.

Pa called to Ma that the threshers had come; then he hurried out to the field with his team. Laura and Mary asked Ma, and then they ran out to the field after him. They might watch, if they were careful not to get in the way.

Uncle Henry came riding up and tied his horse to a tree. Then he and Pa hitched all the other horses, eight of them, to the smaller machine. They hitched each team to the end of a long stick that came out from the center of the machine. A long iron rod lay along the ground, from this machine to the big machine.

Afterward Laura and Mary asked questions, and Pa told them that the big machine was called the separator, and the rod was called the tumbling rod, and the little machine was called the horsepower. Eight horses were hitched to it and made it go, so this was an eight-horsepower machine.

A man sat on top of the horsepower, and when everything was ready he clucked to the horses, and they began to go. They walked around him in a circle, each team pulling on the long stick to which it was hitched, and following the team ahead. As they went around, they stepped carefully over the tumbling rod, which was tumbling over and over on the ground.

Their pulling made the tumbling rod keep rolling over, and the rod moved the machinery of the separator, which stood beside the stack of wheat.

All this machinery made an enormous racket, rackety-banging and clanging. Laura and Mary held tight to each other's hand, at the edge of the field, and watched with all their eyes. They had never seen a machine before. They had never heard such a racket.

Pa and Uncle Henry, on top of the wheat stack, were pitching bundles down on to a board. A man stood at the board and cut the bands on the bundles and crowded the bundles one at a time into a hole at the end of the separator.

The hole looked like the separator's mouth, and it had long, iron teeth. The teeth were chewing. They chewed the bundles and the separator swallowed them. Straw blew out at the separator's other end, and wheat poured out of its side.

Two men were working fast, trampling the straw and building it into a stack. One man was working fast, sacking the pouring grain. The grains of wheat poured out of the separator into a half-bushel measure, and as fast as the measure filled, the man slipped an empty one into its place and emptied the full one into a sack. He had just time

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to empty it and slip it back under the spout before the other measure ran over.

All the men were working as fast as they possibly could, but the machine kept right up with them. Laura and Mary were so excited they could hardly breathe. They held hands tightly and stared.

The horses walked around and around. The man who was driving them cracked his whip and shouted, "Giddap there, John! No use trying to shirk!" Crack! went the whip. "Careful there, Billy! Easy, boy! You can't go but so fast nohow."

The separator swallowed the bundles, the golden straw blew out in a golden cloud, the wheat streamed golden-brown out of the spout, while the men hurried. Pa and Uncle Henry pitched bundles down as fast as they could. And chaff and dust blew over everything. Laura and Mary watched as long as they could.

Then they ran back to the house to help Ma get dinner for all those men.

A big kettle of cabbage and meat was boiling on the stove; a big pan of beans and a johnny-cake were baking in the oven. Laura and Mary set the table for the threshers. They put on salt-rising bread and butter, bowls of stewed pumpkin, pumpkin pies and dried berry pies and cookies, cheese and honey and pitchers of milk.

Then Ma put on the boiled potatoes and cabbage and meat, the baked beans, the hot johnny cake and the baked Hubbard squash, and she poured the tea.

Laura always wondered why bread made of corn meal was called johnny-cake. It wasn't cake. Ma didn't know, unless because the people in the South, where they fought, ate so much of it. They called the Southern soldiers Johnny Rebs. Maybe, they called the Southern bread, cake, just for fun.

Ma had heard some say it should be called journey-cake. She didn't know. It wouldn't be very good bread to take on a journey.

At noon the threshers came in to the table loaded with food. But there was none too much, for threshers work hard and get very hungry.

By the middle of the afternoon the machines had finished all the threshing, and the men who owned them drove them away into the Big Woods, taking with them the sacks of wheat that were their pay. They were going to the next place where neighbors had stacked their wheat and wanted the machines to thresh it.

Pa was very tired that night, but he was happy. He said to Ma:

"It would have taken Henry and Peterson and Pa and me a couple of weeks apiece to thresh as much grain with flails as that machine threshed today. We wouldn't have got as much wheat, either, and it wouldn't have been as clean.

"That machine's a great invention!" he said.

"Other folks can stick to old-fashioned ways if they want to, but I'm all for progress. It's a great age we're living in. As long as I raise wheat, I'm going to have a machine come and thresh it, if there's one anywhere in the neighborhood."

He was too tired that night to talk to Laura, but Laura was proud of him. It was Pa who had got the other men to stack their wheat together and send for the threshing machine, and it was a wonderful machine. Everybody was glad it had come.

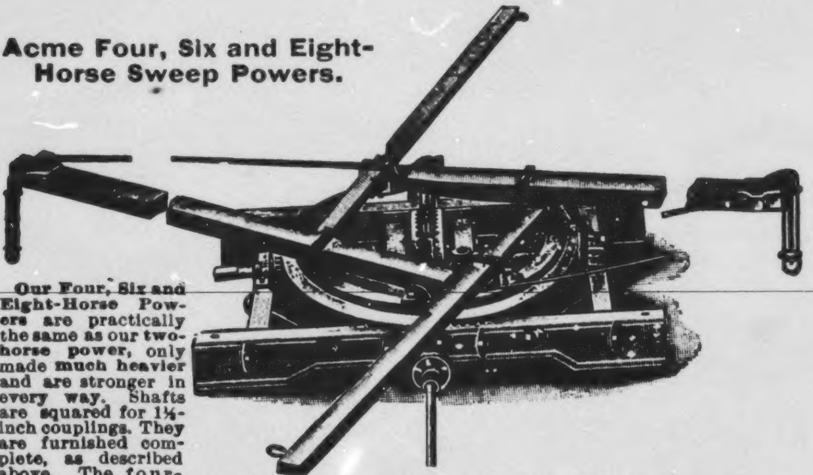
Reading Carefully

1. What time of year was it? How do you know?
2. Draw a rough picture of the threshing machine. Label the parts with the names given in the story.
3. How many "horsepower" was the threshing machine? Where did the energy to run the threshing machine come from? (Follow it back to sunlight.)
4. Do you think using the threshing machine was hard work or an easy job? Why? How many men did it take to run the machine and what did they do?
5. How did Mr. Ingalls feel about the machine?
6. Why was Laura proud of her father?

Thinking It Over

1. In the story, Pa guesses how long it would have taken to thresh the wheat with flails. How many days of labor did the threshing machine save? (Remember, Pa and the other men wouldn't have worked on Sunday.)
2. From the information in the story, make an estimate of how many bushels of wheat the men threshed that day. Show how you calculated it. (Hint – pretend you are sacking half-bushels of wheat, and time yourself with a clock.)
3. What kinds of changes might the threshing machine have made in the lives of wheat farmers like the Ingalls?
4. Pretend you are a horse. Write a paragraph for the "Horse News" describing the new machine from a horse's point of view.
5. Pretend you were a young person at a time when another labor-saving machine was introduced. Write a story about the first time you saw the machine work. Tell where the energy to run the machine came from.

Acme Four, Six and Eight-Horse Sweep Powers.



Our Four, Six and Eight-Horse Powers are practically the same as our two-horse power, only made much heavier and are stronger in every way. Shafts are squared for 1¼-inch couplings. They are furnished complete, as described above. The four-horse power is furnished with two sweeps and two lead poles for two teams, high speed 51 revolutions, low speed 10¼ revolutions to one round of the horses. If wanted with four sweeps, price will be same as for six-horse power. Shipped direct from factory to user.

No. 32R1813 Four-Horse Power. Weight, 1000 pounds. Price....$27.40

No. 32R1814 Six-Horse Power, furnished with four sweeps and speeded same as four-horse power. Weight, 1100 pounds. Price..................$32.40

No. 32R1815 Eight-Horse Power, furnished with four sweeps. High speed 65 revolutions, low speed 12¼ revolutions to one round of the horses. Weight, 1400 pounds. Price...,... .... $43.15

Mr. Wilder Threshes

In the book **Farmer Boy**, Laura Ingalls Wilder describes the boyhood of the man she eventually married, Almanzo Wilder. Almanzo grew up on a prosperous farm in upper New York State near the Saint Lawrence River. This region had been settled for several hundred years and the Wilder family's life represented up-to-date conventional farming, not pioneering the wilderness. Almanzo's father didn't share Mr. Ingalls' feeling about threshing machines.

The flail had come off its handle and Father had put them together again. The flail was an ironwood stick, three feet long and as big around as a broomhandle. It had a hole through one end. Its handle was five feet long, and one end was a round knob.

Father put a strip of cowhide through the hole in the flail, and riveted the ends together to make a leather loop. He took another strip of cowhide and cut a slit in each end of it. He put it through the leather loop on the flail, then he pushed the slits over the knobbed end of the handle.

The flail and its handle were loosely held together by the two leather loops, and the flail could swing easily in any direction.

Almanzo's flail was just like Father's, but it was new and did not need mending. When Father's flail was ready, they went to the South-Barn Floor.

There was still a faint smell of pumpkins, though the stock had eaten them all. A woodsy smell came from the pile of beech leaves, and a dry, strawy smell came from the wheat. Outside the wind was screeching and the snow was whirling, but the South-Barn Floor was warm and quiet.

Father and Almanzo unbound several sheaves of wheat and spread them on the clean wooden floor.

Almanzo asked Father why he did not hire the machine that did threshing. Three men had brought it into the country last fall, and Father had gone to see it. It would thresh a man's whole grain crop in a few days.

"That's a lazy man's way to thresh," Father said. "Haste makes waste, but a lazy man'd rather get his work done fast than do it himself. That machine chews up the straw till it's not fit to feed stock, and it scatters grain around and wastes it.

"All it saves is time, son. And what good is time, with nothing to do? You want to sit and twiddle your thumbs, all these stormy winter days?"

"No!" said Almanzo. He had enough of that, on Sundays.

They spread the wheat two or three inches thick on the floor. Then they faced each other, and they took the handles of their flails in both hands; they swung the flails above their heads and brought them down on the wheat.

Father's struck, then Almanzo's, then Father's, then Almanzo's. Thud! Thud! Thud! Thud! It was like marching to the music on Independence Day. It was like beating the drum. Thud! Thud! Thud! Thud!

Text excerpt from **FARMER BOY** by Laura Ingalls Wilder. Copyright, 1933, as to text, by Harper & Row, Publishers, Inc. Copyright renewed ©1961 by Roger L. MacBride. By permission of Harper & Row, Publishers, Inc.

The grains of wheat were shelling from their little husks and sifting down through the straw. A faint, good smell came from the beaten straw, like the smell of the ripe fields in the sun.

Before Almanzo tired of swinging the flail, it was time to use the pitchforks. He lifted the straw lightly, shaking it, then pitched it aside. The brown wheat-grains lay scattered on the floor. Almanzo and Father spread more sheaves over it, then took up their flails again.

When the shelled grain was thick on the floor, Almanzo scraped it aside with a big wooden scraper.

All that day the pile of wheat grew higher. Just before chore-time Almanzo swept the floor in front of the fanning-mill. Then Father shoveled wheat into the hopper, while Almanzo turned the fanning-mill's handle.

The fans whirred inside the mill, a cloud of chaff blew out its front, and the kernels of clean wheat poured out of its side and went sliding down the rising heap on the floor. Almanzo put a handful into his mouth; they were sweet to chew, and lasted a long time.

He chewed while he held the grain-sacks and Father shoveled the wheat into them. Father stood the full sacks in a row against the wall — a good day's work had been done.

Reading Carefully

1. What was the flail made out of? How big was it? How many pieces did it have? Draw a picture of it.
2. With a partner, pretend you are flailing wheat. Go through all the motions you think Almanzo would, starting with getting the sheaves.
3. Why wouldn't Mr. Wilder use a threshing machine?
4. Where did the energy to thresh the Wilder's wheat come from?
5. Thud! Thud! Thud! Laura Wilder often uses words that sound like a sound. These words are called onamatopoeic words. Can you find another one in the story?

Thinking It Over

1. Can you find any evidence in the description of the threshing at the Ingalls' that would support Mr. Wilder's criticism of the threshing machine?

2. What do you think? Who was right, Mr. Ingalls or Mr. Wilder? Was the thresher a good idea? Would you have used it?

Finding out More Information

1. How is wheat threshed today? Where does the energy to do the threshing come from?
2. Even Mr. Wilder uses a machine, the fanning-mill, to separate the wheat from the chaff. What did people do before there were fanning-mills?
3. Read Chapter 11, "Springtime," in **Farmer Boy**, and Chapter 2, "Springtime on the Claim," in **Little Town on the Prairie.** These chapters describe how farmers in those days prepared the ground and planted the seed. Describe how they did it and where the energy used came from.
4. Read Chapter 25, "The Glittering Cloud," in **On the Banks of Plum Creek.** How did the Ingalls try to cope with the problem described in this chapter? How do farmers cope today? How has the change caused a change in farmers' energy consumption?

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Lesson
continues.

Threshing in Indonesia, 1979

JAKARTA, Indonesia—The women of Java used to hull their rice by hand pounding. But in the early 1970's, mechanical rice hullers were imported from Japan. The predictable happened: Within five years, manual hulling largely vanished from Java.

This may have improved rice production, but it eliminated 133 million work days and $50 million in income per year for the landless women of the island. A researcher named Masri Singarimbun found three mechanical rice hullers and many jobless women in one village. They told him no other work was available.

"Then what will you do?" he asked them. "We will eat more carefully," they replied.

* * *

Development in an agricultural country, experts in the field say, should proceed like this: First, care is taken to promote industries that employ a lot of people using machinery that makes the individual more productive without putting anyone out of work; rural workers then leave the land to take these better-paying jobs: labor turns scarce and wages rise; then agriculture mechanizes and the standard of living generally goes up.

That essentially has been the pattern followed in Japan, Taiwan and South Korea. But Indonesia, by many indications, has worked backwards. Collaborating with foreign manufacturers, it began mechanizing agriculture too soon. Landless laborers who lost their jobs had no place to go.

The disappearance of rice pounding in Java was one case. More recently, foreign companies have been competing to sell cultivating machinery to wealthy Javanese farmers and contractors. In the West Javanese village of Tukdana, an agricultural economist named Rudolf Sinaga found five Japanese-built power tillers in operation. Each of them, he calculated, eliminated over 2,000 days of work per year for village laborers, and diverted $2,650 to the owner, dealer and manufacturer.

A World Bank report warns that these tillers could eliminate more than a million jobs. But sales are rising, to the benefit of foreign manufacturers and their local partners, largely because the government subsidizes the machines with easy credit and low import duties.

Mr. Sinaga believes tillers and tractors should be banned from Java and Bali, Indonesia's most crowded islands. "The only people who like tractors," says one Javanese worker, "are the ones who own them."

Workers pushed off the land are finding fewer jobs available in traditional rural industries. Village makers of bricks, buckets, baskets, rope, soap, shoes and soft drinks have been put out of business by modern factories, many foreign-controlled, that use capital-intensive, labor-saving techniques designed to deal with high labor costs in the West.

Between 1967 and 1975, for example, foreigners invested $500 million in the textile industry alone, mainly for Japanese spinning and weaving equipment. The U.S. Commerce Department predicts that 1980 equipment sales here

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From "Do Multinationals Really Create Jobs in the Third World?" by Barry Newman. (*Wall Street Journal*, September 25, 1979.) Reprinted by permission of the Wall Street Journal, © Dow Jones & Company 1979. All Rights Reserved.

will reach $265 million. Handlooms, which once kept 200,000 women employed, are said to have virtually disappeared.

1. Why did manual hulling disappear from Indonesia?

2. How did Mr. Ingalls get the things he and his family needed to survive? How did the rice pounders get what they needed?

3. A machine that was not driven by human muscle-power took over the threshing done by Mr. Ingalls and by the Indonesian women. Mr. Ingalls was happy but the women weren't. Why? What differences in the two situations made the people feel differently about not having to do the work?

4. The mechanical rice huller eliminated the women's jobs but it created other jobs. What jobs? Where?

5. Who could the farmer afford to pay more, the one person needed to run the mechanical rice huller or the three or more rice pounders?

6. What effect do you think the introduction of the rice hullers might have on the price of rice in Indonesia? Why?

7. In the last half of the 1800s and in the early 1900s, Americans began to use farm machinery to replace human muscle-power with other energy sources. This resulted in less workers being needed on the farm, but it did not result in a lot of unemployment nationwide. Can you think of any reasons that might explain why this was so?

8. The article mentions two things the Indonesian government did that influenced what happened. What were they and were they in favor of or against the use of tillers?

9. The economist quoted in the article, Rudolf Sinaga, suggests the government forbid farmers from buying tillers. If the government did this, what do you think the effect would be on:

The number of jobs in Bali?

the price of rice

the average wage?

10. If you were an Indonesian farmer who had money to buy a tiller, what would you do? What factors would influence your decision?

11. If you were a leader in the Indonesian government, what would you do? What factors would influence your decision?

Tomato-Pickers

"It is a travesty for the government to use tax monies to force people out of work and drive small family farmers off the land," says Albert H. Meyerhoff, regional counsel for California Rural Legal Assistance, a publicly-funded legal services firm representing a group of farm workers in a suit against the university that challenges mechanization.

"Why doesn't the university eliminate free research and development now performed for agribusiness corporations?" he asks.

In reply, university officials defend its role, saying that mechanization keeps California agriculture efficient and competitive—reducing labor uncertainties, costs and paperwork—and in the long run produces more jobs overall than it eliminates.

"It's just too simplified to say that the only beneficiary of mechanization is the one who is riding the tractor or the harvester," says J.B. Kendrick Jr., UC vice president for agriculture. "Mechanization improves the product and keeps prices down."

Through the years, the university has played a role in either the development or analysis of a wide variety of farm machines—sprinkler irrigation systems, smokeless orchard heaters, sugar beet harvesters, shake-and-catch fruit harvesters, electronic tomato sorters.

Most recently the inherent conflicts in replacing men with machines has focused on the development of the tomato harvester—a $60,000 machine now widely used in the gathering of tomatoes for pastes, sauces, juices and other processed forms. California supplies about 85% of the nation's canning tomatoes.

CRLA attorneys, representing a group of 19 farm workers, contend that while tomato tonnage has increased by more than 50% with the development of the harvester, the number of tomato workers has dropped by over 60%—from 50,000 to less than 18,000.

The number of processing tomato growers declined from 4,000 in 1960 to 600 in 1973 according to CRLA. And, the lawyers conclude, the new "square" tomato that was developed to complement the machine is tougher, drier, and less nutritious than its predecessor.

CRLA's Meyerhoff calls the tomato pickers "welfare machines," forcing unemployed workers to draw government benefits and contributing to mechanization's "hidden costs" in urban unrest and crime.

The suit seeks a court order against mechanization research that serves "no valid public purpose" and asks for university funds to assist and retrain displaced farm workers.

University officials stress that agricultural research— like the rest of the vast UC research system—is aimed at benefiting the public generally, not just individual businesses.

From "UC Davis Research Challenged" by Philip Hager. (*Los Angeles Times*, January 22, 1979.) Copyright © 1979 Times Mirror Corporation. Used by permission.

More specifically, the officials defend the tomato harvester as the result of just the kind of research that produces long-term widespread benefits.

"It is largely responsible for saving the tomato industry in this state," says Garrett of UC Davis. "And it opened up a whole new ballgame in farm mechanization."

The development of the harvester, he notes, proved that engineers and plant breeders could work together to produce not only a machine but a different plant the machine could safely handle.

"The old tomato—the fresh tomato that was, and is, sold in the market—was too large, juicy and thin-skinned for the machine and was easily damaged," recalls Garrett. "Now, the new tomato—the one used for processing—is smaller, less juicy and tougher skinned ... and the machine can handle it."

Table tomatoes, for the most part, are still picked by hand.

UC researchers recall that with the demise of contract foreign labor under the bracero* program it had become increasingly difficult to find domestic workers who were willing to pick tomatoes—a task that is hot, hard and irritating to the skin.

The tomato harvester, in an era of increasing farm worker unionization, has reduced the cost and uncertainty of the labor supply and, the researchers add, also brought down the amount of paperwork and other managerial worries that came from large work crews.

And while harvesting jobs decline, they say, other tomato production jobs—hauling, marketing, processing—have increased. They concede that displaced farm workers are not easily absorbed by the job market—many lack the required skills and education—but note that from 1950 to 1976 the number of hired, or nonfamily, farm workers in California declined only from 225,000 to 216,000.

A study co-authored by Garrett points to the historic inevitability of farm mechanization, observing that in 1790, when it took 10 workers on the farm to support one nonfarm worker, that ratio had been reversed by 1935, when one farm worker was supporting 10 nonfarm workers.

"Today, only one of 50 Americans is employed on the farm," the study concluded. "Yet, our nearly unlimited food supply is the envy of the world. Clearly, farm mechanization has played a key role in increasing agricultural production per man-hour and in upgrading the nation's standard of living."

To that, mechanization critic Meyerhoff responds, "Even if we accept the theory that all food in this country some day will necessarily be harvested by machine, we still have to ask who bears the social and economic cost ... As it is now, the farm worker gets nothing and the small farmer gets nothing."

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* A Mexican laborer admitted to the U.S. especially for seasonal contract labor in agriculture.

Reading Carefully

1. How much does a tomato harvester machine cost?

2. What organization developed the mechanical tomato harvester?

3. Since the mechanical tomato harvester was introduced, are more or fewer pounds of "processing tomatoes" being grown in California? Are more or fewer tomato workers employed?

4. How were farm workers hurt by the introduction of the tomato harvester?

5. Name three benefits mentioned in the article that the mechanical tomato harvester provided.

6. Why was it hard for the tomato pickers to find new jobs?

7. The way the problem of mechanically harvesting tomatoes was solved was an innovation: "a whole new ballgame," according to Garrett. What was new and different about the solution?

Thinking It Over

1. Give one reason that might explain why fewer California farms now grow canning tomatoes.

2. Garrett says the tomato harvester "is largely responsible for saving the tomato industry in this state." What does he think would have happened if the tomato harvester hadn't been invented?

3. Describe what you would have to measure to find out which uses more energy per tomato, the tomato harvester system or the hand picked by farm workers system.

4. Meyerhoff says, "The farm worker gets nothing and the small farmer gets nothing." Can you think of some ways they are getting something out of the mechanization of agriculture?

5. If you were the official in charge of approving the budget for a state university, would you approve of spending money to develop agricultural machinery? Give reasons for your decision.

Finding Out More Information

1. The study by Garrett mentions that in 1790 there were ten people on the farm for every one in the city; while today only 1 person in 50 is employed on the farm. Can you think of some jobs that would have been done on the farm in 1790 and are now done in the city?

2. What power-driven machines are used on the farms in the area where you live? When were they introduced? How did they affect the work done on the farm and in the nearby cities?

3. Would you want to be a tomato-picker? What do they earn? Where do they live? How do they get the job? What are the advantages and disadvantages of the job?

Notes

How to Have Lamps Burn Brighter

In these days when lamps are used so much, the care of them is quite an important matter. If the lamps be good and have proper attention, one cannot wish for a more satisfactory light; but if badly cared for they will be a source of much discomfort.

The great secret of having lamps in good working order is to keep them clean and use good oil. Have a regular place and time for trimming the lamps. Put a folded newspaper on the table, so that any stray bits of burned wick and drops of oil may fall upon it. Wash and wipe the chimneys and shades. Now take off all loose parts of the burner, washing them in hot soap-suds and wiping with a clean soft cloth. Trim the wicks and turn them quite low. With a soft, wet cloth, well soaped, wipe the burner thoroughly, working the cloth as much as possible inside the burner, to get off every particle of the charred wick. Now fill the lamps within about one inch of the top, and wipe with a damp towel and then a dry one. Adjust all the parts and return them to their proper places.

Whenever a new wick is required in a lamp, wash and scald the burner before putting in the wick. With a student lamp, the receptacle for waste oil, which is screwed on the bottom of the burner, should be taken off at least once a week and washed.

Sometimes a wick will get very dirty before it is half consumed. It is not economy to try to burn it; replace it with a fresh one. The trouble and expense are slight, and the increase in clearness and brilliancy will repay the extra care.

When a lamp is lighted, it should not at once be turned up to full height; wait until the chimney is heated. Beautiful shades are often cracked or broken by having the hot chimneys rest against them. Now, when lighting a lamp, be careful that the chimney is set perfectly straight, and does not touch the shade at any point. The shade should be placed on the lamp as soon as it is lighted, that it may heat gradually.

Lamp Burners. - At least once a month lamp burners should be boiled in strong, soapy water; lamp wicks should as often be washed in soap suds; lamp chimneys should not be washed but moistened with steam, wiped with soft linen, and polished with paper. A cloth and kerosene give a good bright surface.

Keep Your Oil Lamp Full. - Scarcely a day passes that we hear of fearful accidents and disastrous fires occasioned by the explosion of kerosene lamps. A fruitful source of danger from this course lies in the neglect to keep the lamp full. If a lamp is neglected, and allowed to burn low, inflammable gas gathers over the surface, which a slight jar inflames, and an explosion follows. Lamps in daily use should be filled every morning.

From *The Household Guide or Domestic Encyclopedia* by B. G. Jefferies and J. L. Nichols. Atlanta, Georgia: J. L. Nichols & Company 1892. p 358. Reparagraphed.

Notes

Lights on Broadway

If electric lights were an expensive new novelty, who do you think would be the first to use them on a grand scale? If you answered "show business," you're right. Theaters in London and New York were among the first to use large numbers of electric lights, not only in the theater but outside as well. In New York City the theater district, on Broadway, became famous as the "Gay White Way" because of its brilliant illumination. Today this area is still often called the "Great White Way."

The small beginnings of the "Gay White Way" occurred in the early eighties of the last century. In 1881 the energetic and astute London manager, D'Oyley Carte, introduced the electric light in his newly built Savoy Theatre, the birthplace of most of the Gilbert and Sullivan operas of delectable memory. This was said to be the first building entirely illuminated by electricity. Rudolph Aronson, projector and manager of the New York Casino, recognizing its pronounced advantages in theatre lighting, installed it in his pretty home of light opera on Broadway and Thirty-ninth Street, which opened the following year. It is difficult in this age, when it has become a commonplace, to conceive the charm of the new illuminant. From indoor lighting the incandescent lamp made its way to outdoor uses, and the old windblown gas jet gradually found its place usurped by the trim and saucy electric bulb, and flickered to its end. Street signs and entrances to public places became gay with this Promethean gleam, which not wind nor rain might quench, until finally it reached the roofs of the houses bearing the legends of trade. So much for the genesis of our modern pyrotechnic highway.

The heart of the region now known as the "Gay White Way," in the early days spoken of, was to the average playgoer terra incognita. Long Acre Square, as it was then designated, was a monotonous open space, bordered by rows of drab apartment houses and dingy dwellings, of which latter there are still one or two tenacious survivors. Its most conspicuous buildings were the hotel, still standing, and the 12th Regiment armory, on the site of which Oscar Hammerstein erected his trail-blazing palace of amusements, "Olympia," now the New York and Criterion Theatres. Northward of the square the huge factory of the famous Brewster carriages introduced the wayfarer to a region chiefly devoted to equine matters. The sound of the blacksmiths' hammer mingled with the tinkle of the horse-car bell. Stables abounded, and here and there a red flag indicated a horse auction. Florid men, wearing white stocks and horseshoe pins, stood about discussing the merits of equine bargains, for in those days my lady drove to the play behind a pair of spanking high-steppers, and horse-sense ruled. By night this district, now ablaze, was as dark as Egypt, save for the dim lights of an occasional livery-stable, a corner saloon, or a city street lamp.

From "When the Gay White Way Was Dark," by S. Rosenbaum, in *Valentines Manual of Old New York #7, New Series*, edited by Henry Collins Brown. (NY: Valentines Manual, Inc. 1923.) Copyright © 1923 Henry Collins Brown

Reading Carefully

1. How did people get to the theater?

2. What kind of lights did the electric lights replace?

3. Was the electric light first used commercially indoors or outdoors?

Thinking It Over

4. What does the author mean by "the legends of trade"?

5. The author implies there were a number of problems with gas lights. List some of them.

6. Can you think of something in your life that was exciting or charming when you first encountered it, and now seems commonplace?

7. Suppose there were no electric lights in your town. Write a description of your local business district after dark.

Finding Out More Information

8. How old was the "old windblown gas jet" at the time Mr. Rosenbaum describes?

9. What does the author mean by "Promethean gleam?" Who was Prometheus?

10. What do the following phrases mean?

public places

pyrotechnic highway

terra incognita

tenacious survivors

florid men

Lead Time: A Puzzle For Planners

Objectives

This lesson contributes to the students' understanding of the following ideas:

Years or decades are required to plan and build major energy installations; there are limits to how fast this process can be speeded up whatever the urgency.

Because of lead time requirements, we are deciding now what major energy facilities will be available in the 1990's.

Methods can be worked out for determining the fastest way of building a major facility.

Increasing lead times mean increases in the costs of building a facility, because of the interest on the capital that is not yet productive.

Format of the Lesson

More than one class period is needed for this lesson, since students need to take the second worksheet home and puzzle over it.

Preliminary discussion of "doing things"

Pass out worksheet, **Baking a Cake**

Silent work period

Class review of solution on chalkboard

Arrange class in groups

Pass out worksheet, **Lead Time, a Puzzle for Planners**

Silent work period; teacher circulates

Subsequent Periods

Supervised group work

Presentation and discussion of results

Calculation of effect of increasing lead time on interest costs

Historical data

Materials Needed

activity sheet **Baking a Cake,** one for each student.

activity sheets **Lead Time, a Puzzle for Planners,** one set per student.

scratch paper, pencils and erasers, Scotch® tape.

overhead transparency, puzzle solution.

Teacher Background

Students, like the general public, often fail to appreciate how long it takes to plan and build any large energy installation, such as a refinery, power station, or even a factory for solar collectors. To have electricity from a new power station available for today's seventh graders when they graduate from college, a commitment to build the plant must be made now. So we are making our energy decisions for the 1990's right now. We will not be able to change our minds later and create instant capital equipment in a crash program.

Lead time for electric power stations has been lengthening; more so in this country than abroad. One reason for this are new environmental concerns and the way these concerns have been embodied in legislation. Expansion of lead times also increases the cost of the plant (and so the cost of the electricity it produces), because it increases the length of time money is out before it starts earning a return. (Utilities are not ordinarily allowed to add the cost of a new station to their "rate base" until it is in operation and actually supplying electricity to customers).

Preliminary Discussion

Ask students if they ever made something that took planning ahead, such as a special dinner or a model airplane, or helped a parent install something. Encourage the students to talk about what they did.

Question students who respond to bring out that most projects involve a number of separate tasks. One way to do this is by summarizing the student's description: "O.K., let me get this straight. First you, then you, then you..."

Go back and ask students if they had any idea before they began their project how long it would take. How did they make their estimate?

Summarize that many projects involve a number of different tasks that have to be done in some order, more or less. Part of planning how to do something is knowing what to do, but also knowing what order to do things in and how long it will take to do.

Tell the class we're going to work on a puzzle. We're going to try to figure out how long it takes to do something if you know how long all the individual parts of the job would take.

The "cake" activity is provided as preparation for the more difficult activity that follows. It gives students an opportunity to become familiar with the charting technique by practicing it on a simple familiar project before considering a more complex one.

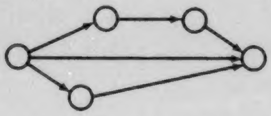
Baking a Cake

Pass out the **Baking a Cake** worksheet and suggest students look it over. Ask for a show of hands on how many people have ever helped bake a "scratch" cake.

Tell students this is a list of things to do to make a cake. We want to make a chart to show in what order we do these things. To do this, we'll identify the jobs by the numbers given them on the sheet. What number would we begin with? (ANS: 14, recipe.) Write 14 in a circle on the left hand side of the chalkboard. What number will we end with? (ANS: 17, eating the cake.)

Draw a circle next to the right of the 14 circle and connected to it by a line. State that this would represent the next thing we'd have to do. What would that be? (ANS: 4, buy the ingredients.)

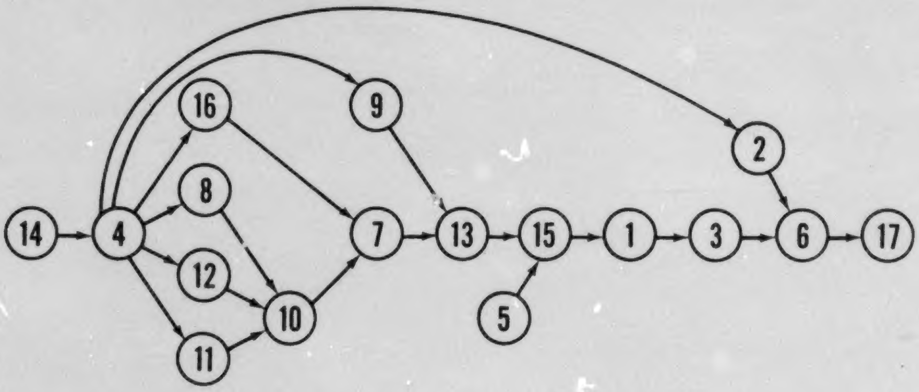
Ask the class to take out paper and pencil and make a complete path from 14 to 17, including all the steps. Mention it won't be a straight line because sometimes you may be doing three things at once, so you could do something like this. Draw a disconnected branch in the middle of the board, viz,



then erase it. While the students are working, circulate to help those who are having trouble.

Class Review of Solution

The solution looks like this:



duration of lengthiest task in each leg
20m 45m 10m 5m 15m 0m 45m 0m 20m 10m 0m

elapsed time since start of project
20m 1h5m 1h15m 1h20m 1h35m 2h20m 2h40m 2h50m

Elicit it number by number from the class, drawing it on the chalkboard as you go.

When the chart is completed and the students understand how it was created, discuss the time factor. This is straightforward except for getting from 4 to 7, because there are four different paths, 4-16-7, 4-8-10-7, 4-12-10-7, and 4-11-10-7. Help students see that getting from 4 to 7 will take as long as it takes to do the lengthiest set of tasks between four and seven. Because task twelve takes longer than tasks eight or eleven, the length of time it takes to do the path 4-12-10-7 will be the length of time it takes to get from four to seven.

Calculate the time required from the chart, using the longest time between any two points.

Now divide the class into groups and arrange the room appropriately if necessary.

Lead Time

Pass out the worksheet, **Lead Time: A Puzzle for Planners.** Ask the students to solve this problem as they did the earlier one.

This is obviously a far more difficult problem than the cake. Simply reading the tasks may consume most of the time remaining in the period.

When the students first begin to work on the chart, an adult resource should be available. A helpful way of getting started is to make a chart by taping together pieces of ruled paper. Let each line represent a month. Start at the end and work backwards, making liberal use of an eraser. Monitor the progress of groups to determine when it will be appropriate to begin the class review.

Reviewing the Rules

Ask who has been able to do the job in the least number of months. Take the team with the least number of months and have them put their chart on the board, month by month, asking the class if it agrees the solution is possible. It is impossible to predict how long this will take because classes vary greatly in the frequency and accuracy of objections raised to the solution. On the next page is the fastest plan we could work out.

Conclude by asking if anyone has any improvements to add. Your chart should then look something like ours, but it isn't important that it be an exact dupliduplicate.

A master for making an overhead transparency of the solution is provided, to save the tedious job of copying it onto the board.

Computing the Interest

Notice along the bottom of the chart are two lines of figures. The first line shows the amount of money spent that year. The second shows the cumulative total. There are some interesting facts to be noted about these series of figures.

First, notice that expenditures in early years are much lower than in later years. The money really starts to flow when large numbers of workers are added and heavy equipment is purchased.

Point out that the money spent on construction does not begin to earn money until the plant begins to generate electricity. Calculate what the interest in some of the years would be at the current prime rate.

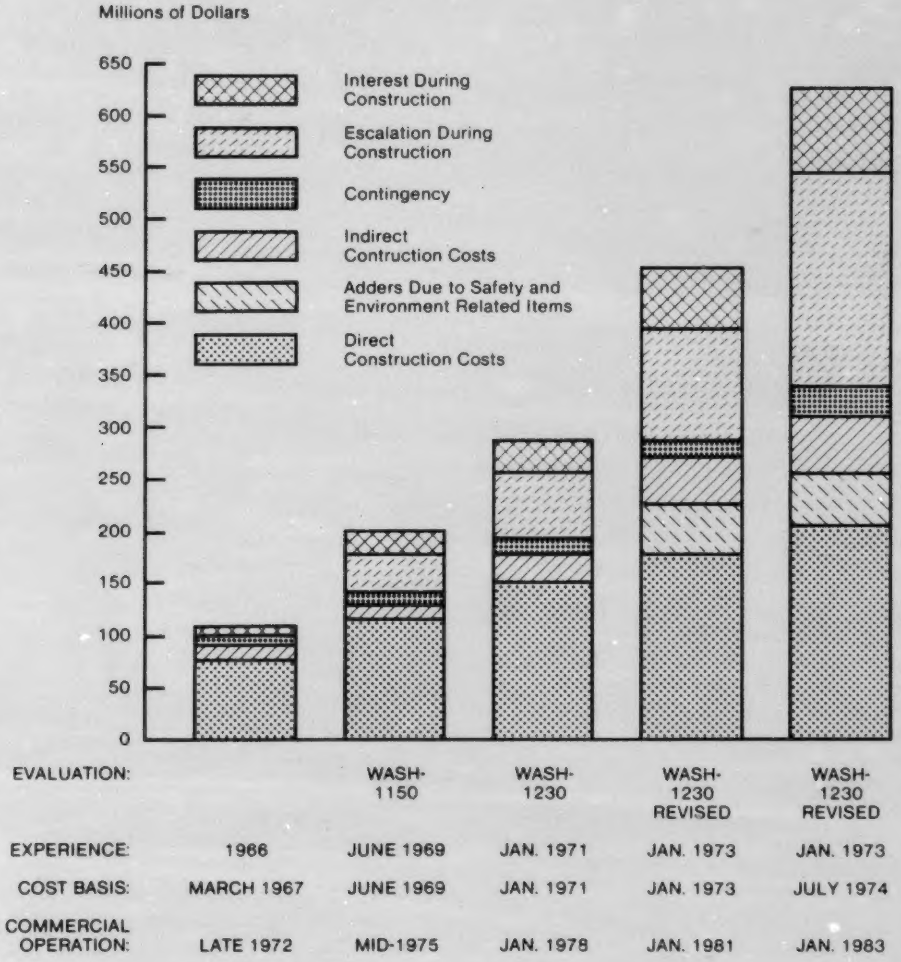
Here is a trick question: if one plant costs $900 million in labor and materials to build and takes five years, and another costs $900 million and takes 10 years, which costs more? The second costs more because you will have to pay five extra years' interest.

Some Historical Data

So that the students can see the practical application of what they've been doing, here are some figures you can share with them on the escalation of lead times and interest expenses over the past ten years.

Comparison of Plant Cost Estimates
(Total Investment for 1000 MWe Plants)

Coal Fired



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Lesson
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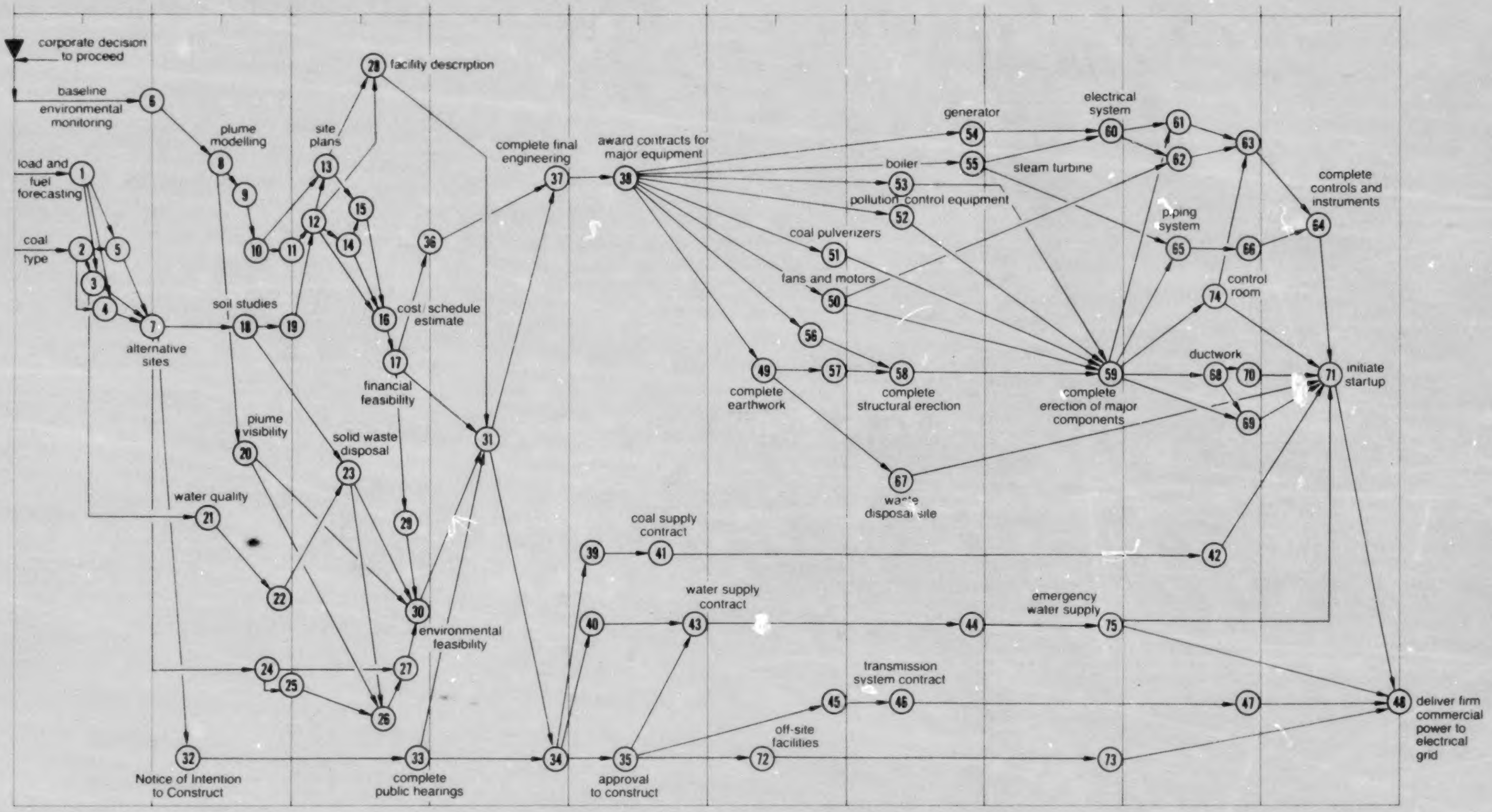
Baking a Cake

You are baking a cake for company with the help of two friends. Because there are three of you, you can do more than one thing at a time. The cake must be ready by six o'clock. If you have to do all the steps below (which aren't in any order), when will you have to start in order to finish by six?

1. Remove cake from oven. Can't be done until cake is baked.
2. Mix frosting. Takes ten minutes. Can't be done until ingredients have been bought.
3. Remove cake from pan, place on wire rack, and let cool. Takes twenty minutes, can't be done until cake is out of oven.
4. Go to store and buy ingredients. Takes 45 minutes, can't be done until recipe is selected.
5. Preheat oven. Takes five minutes.
6. Frost cake. Takes 10 minutes, can't be done until frosting is mixed and cake is cool.
7. Combine wet and dry ingredients and beat for 100 strokes. Takes 15 minutes. Can't be done until milk, shortening and eggs have been combined and dry ingredients have been sifted.
8. Measure milk. Takes 5 minutes, can't be done until ingredients have been purchased.
9. Grease and flour baking pans. Takes 5 minutes, can't be done until ingredients have been purchased.
10. Combine milk, shortening, and eggs. Takes 5 minutes, can't be done until eggs have been beaten, milk has been measured, and shortening has been melted.
11. Beat eggs. Takes five minutes, can't be done until ingredients have been purchased.
12. Melt and measure shortening. Takes 10 minutes, can't be done until ingredients have been purchased.
13. Pour batter into baking pans. Can't be done until wet and dry ingredients have been mixed and pans have been greased.
14. Look through cookbooks and select recipe for cake. Takes 20 minutes. Do this first.
15. Put cake in oven and bake for forty-five minutes. Can't be done until oven is preheated and batter has been poured into pans.
16. Measure and sift flour and other dry ingredients. Takes ten minutes, can't be done until ingredients are purchased.
17. Eat the cake.

Tasks Required for Construction of a 1000 MWe Coal-fired Powerplant

Years from start of project


corporate decision to proceed
baseline environmental monitoring
load and fuel forecasting
coal type
plume modelling
site plans
facility description
complete final engineering
award contracts for major equipment
generator
electrical system
boiler
steam turbine
pollution control equipment
coal pulverizers
fans and motors
piping system
control room
complete controls and instruments
soil studies
alternative sites
cost/schedule estimate
financial feasibility
plume visibility
solid waste disposal
water quality
complete earthwork
complete structural erection
complete erection of major components
ductwork
initiate startup
waste disposal site
coal supply contract
water supply contract
emergency water supply
environmental feasibility
transmission system contract
off-site facilities
deliver firm commercial power to electrical grid
Notice of Intention to Construct
complete public hearings
approval to construct
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Annual Expenditure (in millions)	$20	$50	$50	$80	$150	$250	$300	$250	$200	$100
Cumulative Expenditure (in millions)	$20	$70	$120	$200	$350	$600	$900	$1150	$1350	$1450

Note: a 1980 start date is assumed, with costs (including AFDC) in 1980 dollars.

Lead Time: A Puzzle For Planners

You are planners for a large electric utility. Your job is to decide when to begin constructing new power plants to meet increasing demand for electricity. Conservation and load management measures, including new time-of-day power meters, have successfully reduced the increase in peak demand for your electricity to 2% per year. Your electrical system does not contain old plants that it would be practical to renovate or repower.

You cannot buy electricity from neighboring utilities. They are all facing power shortages too and are already asking to purchase power from you.

You have looked into what fuels might be available in the future. After a long and stormy debate within the company, top management has decided to build a large coal-fired power plant, to be operating by the time that you predict extra power will be needed.

As planners, you have tried to predict how much electricity your customers will want in future years, and have compared that with your estimate of what generating equipment will be available. This forecast shows that the difference between generating capacity and projected peak demand is expected to drop to a dangerous level (below 10%) after 1990. This means that by 1990, more than 90% of all your existing facilities must be operating at full load (including plants which must be shut down for maintenance). If they aren't, your company must turn off the electricity, causing a rolling blackout during periods of peak demand.

In order to minimize the risk of power shortages or rolling blackouts, you recommend that a 1000 MWe coal-fired power plant be constructed by 1990.

Management asks two questions:

1. When do we need to start obtaining permits and building the plant, so that it will be running by 1990?
2. How many new power plants do we have to start building to meet the forecasted electrical demand before the first plant actually begins operating (and earning money) in 1990?

As chief planner, you have requested scheduling information from people who work for you. They have come up with 75 tasks. Now you need to put these tasks in the form of a network (as you did with "Baking a Cake"), so that the total time required for the project can be determined. (Hint: Try using ruled 8½ × 11 paper, turned sideways, making every line equal to one month. Tape several sheets together to make one long skinny piece with vertical lines. Do your work in pencil. If you have trouble getting started, try beginning with the completion of the plant in 1990 and working backwards.)

Building a Coal-Fired Power Plant: Jobs That Have to be Done

This is a list of tasks that would have to be done to build a coal-fired powerplant. (We've assumed the studies at the beginning would show coal was the best fuel for the circumstances.) For each task, an estimate of the number of months it would take is also given. These estimates are educated guesses based on times required in 1979, and also assume a plant size of 1000 MWe. This is less than ½ of 1% of the current coal-fired capacity in the USA. Considering that we don't know where the plant will be, what the air pollution requirements are, how far away the mine is, and so on, the estimates are as realistic as possible.

The tasks are not necessarily listed in the order that they would be done.

	Months	Tasks We Have to Finish First
1. The utility estimates how much electricity it will be expected to supply in 1990. It also estimates how much fuel will be required to produce the electricity and whether it will be available. Begin as soon as the utility company decides to go ahead.	6	"go ahead" decision
2. Find a source of coal. In the laboratory, test samples of the coal to find out how many Btu's it produces per ton, how much sulfur is in it, how much slag it produces, and other things you need to know to design the plant. Can't begin until the utility company makes a decision to go ahead.	6	"go ahead" decision
3. Water is needed to run a fossil-fuel plant. The utility searches the region where the plant might be located to find possible sources for the amount of water needed.	1	1, 2
4. A power plant needs paths for coal and equipment to get to the plant and for electricity and wastes to leave. The utility company examines the region to see where transmission line corridors, railroad tracks, slurry pipelines, solid waste disposal areas, and road might be put.	2	1, 2

	Months	Tasks We Have to Finish First
5. The people who will operate the plant have to live somewhere; they need permanent homes, and the people who build the plant will need temporary homes. They will need water, schools, roads, food stores, and a lot of other things. The utility estimates how many people will be required, what they will need, and how able the reion would be to provide the services the people need.	3	1, 2
6. In order to know whether the plant has caused any changes in the environment, we need a record of exactly what the environment was like before the plant was built. The utility sends out scientists to spend a year measuring the environment in the region where the plant will be built. Begin as soon as the utility company decides to go ahead.	12	"go ahead" decision
7. Now we know something about the region's human and physical resources, and its environment. The law requires the utility to select three possible choices of a site for the power plant. The utility now purchases the sites or otherwise obtains the right to use of the land.	3	3, 4, 5
8. Pollutants can be carried downwind from a power plant in the "smoke" from the plant. We need to know where this smoke will go and how concentrated it will be at all locations. To predict this, the utility uses a computer to process information on the size of the plant, the weather conditions, and even the hills and valleys surrounding the sites.	6	6
9. The utility's engineers calculate how high the smokestack should be and what kind of pollution control equipment will be needed to prevent significant deterioration of the air quality at ground level downwind.	2	8
10. The allowable smokestack emissions from each of the three sites will be a little different. The utility makes a first rough estimate of how those differences would affect a power plant.	1	9

	Months	Tasks We Have to Finish First
11. Now the engineers who will design the plant need to get a rough idea on the size of the flows of energy and material through the plant. They do this by preparing flow diagrams that show where everything comes from and where it goes.	3	10
12. Using the flow diagram, the engineers figure out roughly how big all the major pieces of equipment (like the boiler) will be and their shapes.	2	11 and 19
13. For each of the three sites, the utility prepares a map showing where the buildings and roads would be.	1	10 and 12
14. Some of the pieces of equipment needed will take a long time to make, especially if manufacturers already have a lot of orders and we must wait our turn. The utility makes a shopping list of everything which will take a long time to obtain.	3	12
15. To begin planning how the contractor will build the plant, the utility makes a rough estimate of the order in which the largest pieces of equipment will have to be installed.	1	13 and 14
16. For each of the three possible sites, we need to prepare a rough estimate of costs and schedule.	2	12, 14, 15
17. Now that we have a better idea of what would be involved in building on each of the three sites, the utility company accountants can compare how expensive it would be to build and operate a plant at each of the three sites.	1	16
18. To build foundation strong enough to support something as heavy as a powerplant, you need a good idea of what the ground underneath is like: how far down bedrock is, whether there are earthquake faults nearby, and so on. To find out, the utility geologists drill holes and conduct field studies.	8	7
19. Now that we know the geology of the ground we're building on, the utility's engineers can make a rough design of each foundation.	4	18

	Months	Tasks We Have to Finish First
20. We don't want the plant to be an eyesore. The structures should fit the setting and the plume should not be too visible. This is harder to achieve in some places than others; the utility evaluates the three possible sites for aesthetic factors.	2	8
21. The three sites may not have the same water. Some water may have more minerals than others, or the water may dry up at certain seasons. The utility investigates the water supply at each site.	10	3
22. The plant will produce some liquid wastes. To minimize the amout of liquid waste, the utility hires process engineers to study how to reuse salty water and avoid buildup of harmful deposits inside the plant.	6	21
23. Burning coal leaves ashes, and the ashes contain some harmful trace elements. The utility plans what it will do with the ashes and studies whether, for example, rainfall will wash harmful materials out of the ashes into rivers or the watertable.	6	18 and 22
24. For each of the three sites, utility planners figure out how many workers would be needed and what community developments would be needed to support them.	10	7
25. For each of the three possible sites, utility engineers determine all the transportation improvements that would be needed (roads, railroad tracks and sidings, piplines, powerline corridors, and so forth).	2	24

	Months	Tasks We Have to Finish First
26. The utility hires archeologists, biologists, and other experts to evaluate the effect constructing and operating the plant will have on historic and archeological features, on wildlife, including vegetation, on other forms of land use by humans, and so forth, at each of the three possible sites.	3	20, 23, 25
27. The utility hires sociologists to predict what effect construction of the power plant at each of the three possible sites would have on the life of the people in the region.	2	24 and 26
28. The utility's engineers pull the engineering information together and make a complete description of the powerplant for each of the three possible sites.	4	12 and 13
29. The utility hires economists to make a study of the effect the power plant will have on the economy of the region.	1	17
30. The engineers have determined, for each site, approximately what a plant meeting current environmental regulations would be like. Now the utility's cost analysts determine which of the three sites is the most feasible in terms of paying back the money required to build the plant.	1	20, 23, 27 and 29
31. The economic and environmental feasibility of the three sites are compared in the Final Environmental Impact Statement, and a single site is recommended. For a typical power plant, this will be a set of three-ring binders about three feet high.	6	17, 28, 30 and 33
32. The utility submits a *Notice of Intention to Construct* a coal-fired power plant to government agencies. This starts the regulatory review process.	3	7

	Months	Tasks We Have to Finish First
33. The utility staff fills out the necessary forms and provides information. The government agencies hold public hearings and examine the information to determine whether building the plant will be in the public interest and will conform to legal requirements. Among the interested agencies would be:	20	32

Federal

- Department of Energy
- Environmental Protection Agency
- OSHA (Occupational Safety and Health Administration)
- Department of Interior (USBR, Park Service, etc. as appropriate)
- Federal Bureau of Mines
- Department of Agriculture (Forest Service, Bureau of Land Management, as appropriate)
- Department of Transportation (ICC, FAA, FCC, Federal Highway Commission, Federal Railway Commission, etc. as appropriate

State

- Public Utilities Commission
- Air Resources Conservation Commission
- Water Conservation Authority
- Department of Fish and Game
- Park and Wildlife Commission(s)
- Soil Conservation Authority
- Department of Highways

County

- Air Pollution Control District
- Building Permits
- Sanitary Landfill Permits

	Months	Tasks We Have to Finish First
34. The key regulatory agencies give their preliminary approval. To save time, the utility sends various manufacturers a shopping list describing the major pieces of equipment it wants to buy, and asks them "how much?"	6	31 and 33
35. Government agencies complete their study of the project and grant final approval.	6	34
36. The utility selects an engineering-construction company to design and construct the power plant.	3	17
37. The engineers complete most of the final design and prepare a description of the major items that will need to be made to order (like boilers, pumps, transformers, and so forth).	6	31 and 36
38. Manufacturers who are interested in supplying equipment study the bid specifications and decide how much money they would ask to build the items. They issue quotes to the utility, who reviews and selects a manufacturer the best suited to do the work. Contracts are signed as soon as the utility receives final regulatory approval.	6	37
39. The utility and the company who will supply the coal work out an agreement about quantity and quality of coal, delivery schedules, and price.	3	34
40. The utility negotiates a price with whoever has water rights.	3	34
41. The coal supplier will have to increase the amount of coal it can mine each day in order to provide the new amounts needed for the new power plant. The mine may need more equipment, more transportation facilities like railroad sidings, drag lines, new mineshafts, and so on. (Note - the mine will probably have to go through the same engineering and issuing of bids to manufacturers that the utility did for the power plant. It will also have to obtain the approval of government regulatory agencies. It is assumed that regulatory approval for expansion of coal mining and transportation facilities have been obtained with the power plant approval process.)	6	39

	Months	Tasks We Have to Finish First
42. The coal supplier begins delivering coal to the powerplant site. On the site, the contractor prepares a place for holding a pile of coal big enough to keep the powerplant operating during an interruption of coal deliveries. The first deliveries of coal will be used to build up this stock pile.	48	41
43. Whoever will be supplying the water (it may be the utility itself or it may be another company or agency) issues contracts to construct facilities to supply and store the water, such as pipelines, reservoirs, intake structures if the water is being drawn from a river, and so on.	6	35 and 40
44. Pipelines are constructed and water starts coming to the site.	24	43
45. A team of negotiators from the utility completes the task of buying rights-of-way for the transmission corridors and other pieces of land needed besides the powerplant site itself.	18	35
46. The utility awards a contract to a construction company to put up the transmission line and the switchyard.	6	45
47. The construction company puts up all the towers for the transmission lines, strings the cable, and tests the system.	30	46
48. The plant operators spend six months starting up the equipment and adjusting all the controls. Complete testing on air and water is followed by lighting off the boiler and eventually bringing all the systems to full operating capacity. When this work is completed, the plant goes "commercial" and begins supplying electricity on a regular, reliable basis.	6	47, 71, 73 and 75
49. With bulldozers and other earthmoving machinery, the contractor grades the entire powerplant site according to plans.	12	38

	Months	Tasks We Have to Finish First
50. A manufacturer makes the fans which force air through the boiler, the pollution control equipment, and out the stack; and delivers them to the powerplant site. The motors for the fans are manufactured and delivered. For a 1000 MWe plant, perhaps four fans of 7,000 HP each would be required.	18	38
51. A manufacturer makes the machines which will break the pieces of coal into a powder which can be easily moved into the boiler using air from the fans. The machinery is delivered to the powerplant site.	18	38
52. A manufacturer makes the equipment needed to control air pollution from the plant: this might include fabric filters to collect noncombustible ash, wet scrubbers to remove sulfur dioxide, or some other technologies.	24	38
53. A manufacturer makes the boiler (the boiler will weigh something like 2,000 tons). It is delivered to the power plant site in small pieces.	24	38
54. A manufacturer builds and delivers the generator, transformers, and switchgear.	30	38
55. A manufacturer builds the high, intermediate and low pressure steam turbines. (The low pressure turbine weighs around 300 tons). The turbines are delivered to the powerplant site.	30	38
56. A steel company makes the structural steel (columns and girders) that will be used to hold the boiler and steam turbines in place, and delivers it to the powerplant site.	16	38
57. The contractor places the concrete foundations for the powerplant and locates anchor bolts.	6	49
58. The contractor completes erection of the structural steel.	6	56 and 57

	Months	Tasks We Have to Finish First
59. The contractor finishes placing the major equipment components. These include the boiler shell, the air pollution control equipment, the fans that drive air into the boiler and through the air pollution control equipment, various electric motors, pumps, and the condenser.	18	50, 51, 52, 53 and 58
60. The contractor places the turbine/generator set in position and the transformers and switchgear are installed.	12	54 and 55
61. The contractor mounts cable trays on the structural steel to hold the electrical and control cables and wiring.	6	59 and 60
62. The construction crew installs the smaller electric motors and their control centers.	6	50 and 60
63. The heavy wire cables that will carry the electricity are installed. So is the wiring for the electrical controls for the powerplant.	3	61, 62, 74
64. In the powerplant there are many measuring instruments and controls. Each of these is checked against standards and adjusted if necessary.	6	63 and 66
65. The contractor installs the major piping to carry water and steam. The circulating water lines are about 12 feet in diameter and the high pressure steam piping is typically about 2 feet in diameter, with a 2-inch thick steel wall.	6	55 and 59
66. When the large diameter pipe has been hung on the structural steel, then the small pipe (less than 2-inches diameter) and the pressure lines for instrumentation are installed and connected.	6	65
67. The facilities to handle the solid wastes produced by the plant are constructed. This would include a flyash storage silo capable of holding 500 tons of flyash.	12	49
68. The contractor erects the ducts which will supply air to the boiler, and builds the flue gas passages to take the waste gases to the chimney.	9	59

	Months	**Tasks We Have to Finish First**
69. The contractor completes the erection of the chimney. The chimney is probably 500 to 800 feet tall, and contains several thousand tons of concrete. As soon as the ductwork is completed, work starts to hook up the chimney.	12	59 and 68
70. The contractor insulates the boiler and the ductwork. Aluminum sheet metal, called lagging, is placed over the insulation to prevent heat losses.	3	68
71. The operating crew begins start-up operations: they turn on each motor, wash the steam lines with acid and blow them clean, pressure test all air and water lines, and start the auxiliary boiler. All the controls and relays have to be adjusted during tests carried out over several months.	1	42 64, 67, 69 70, 74, 75
72. The utility signs contracts for the construction of facilities which will be needed on sites other than the power plant site. (Housing, maintenance shops, warehouses, auxiliary fuel storage, etc.)	12	35
73. The contractor completes construction of all the offsite facilities.	30	72
74. At the power plant site, the contractor completes the administration building, maintenance shops, and the control room with its instrument panels.	9	59
75. The emergency water supply reservoirs are filled.	12	44

One Year's Direct Energy Consumption in My Home

You have been studying a flow diagram of all the energy used in the United States in one year. In this exercise you will make a flow diagram for the energy used in your household in one year.

We cannot show many of the energy inputs to your household on this diagram, because it would be too difficult to estimate exactly how large they were. For example, the energy it took to produce your food, your clothing, and all the other things you bought is not included. We will include only your **direct** use of energy. If we could include **all** the energy your household used, the bars would be much bigger.

You can do this activity at home. You do not have to show your diagram to anyone at school.

Your teacher will give you a special graph to use in making your flow diagram. On the bottom are scales that will convert your energy purchases from physical units, like gallons of gasoline, to Btu's. On the graph, all energy is measured in Btu's.

Your teacher will show you an example of a completed graph. Shading the flows in different pencil colors makes a good-looking diagram.

You can use the spaces below to enter your household direct energy purchases from the records you made earlier.

One Year's Energy Purchases

Gasoline ____________ gallons

Fuel oil ____________ gallons

Wood ____________ cords

Electricity ____________ kilowatt hours

Natural gas ____________ therms

Diesel fuel ____________ gallons

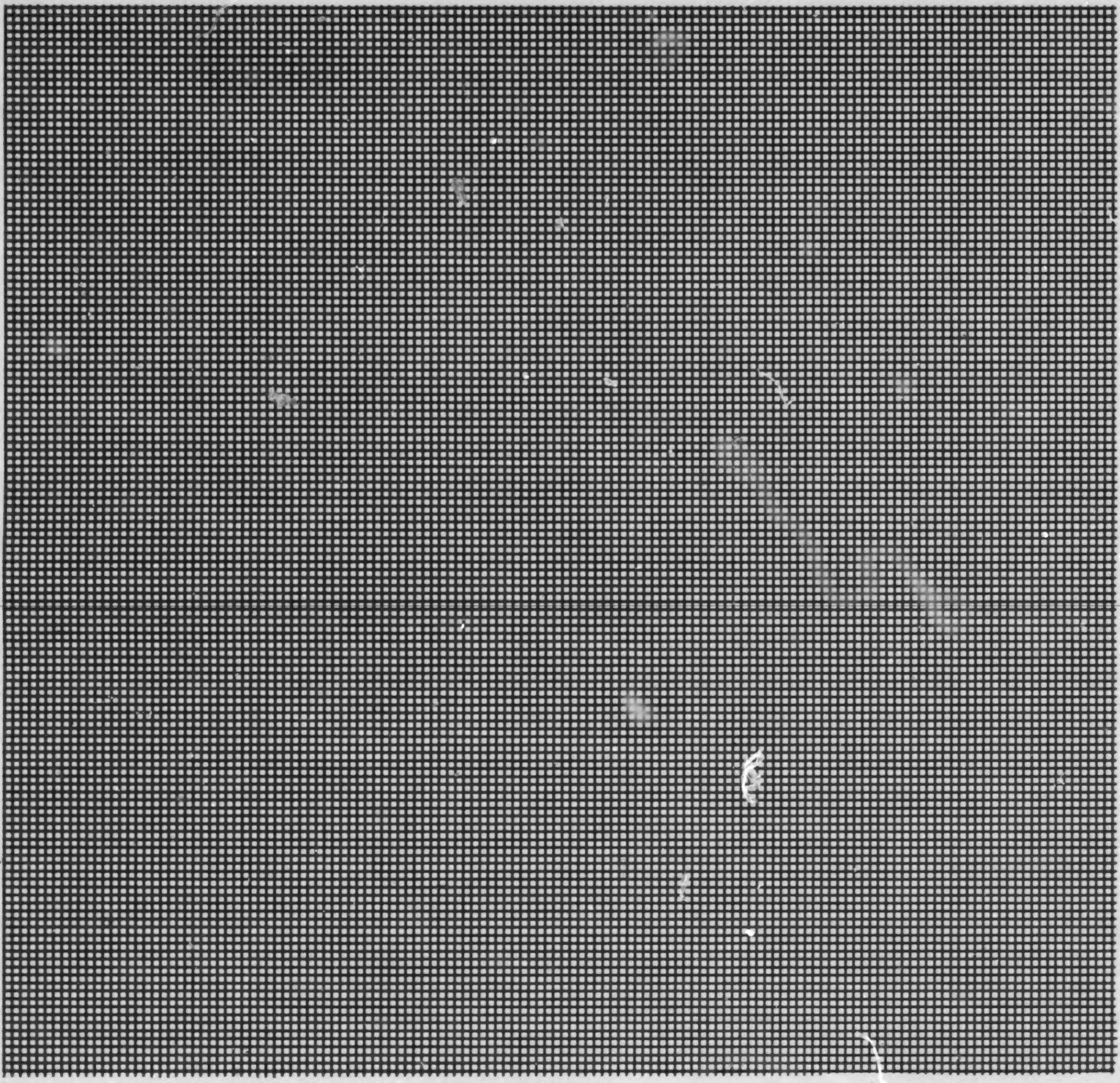
Propane ____________ gallons

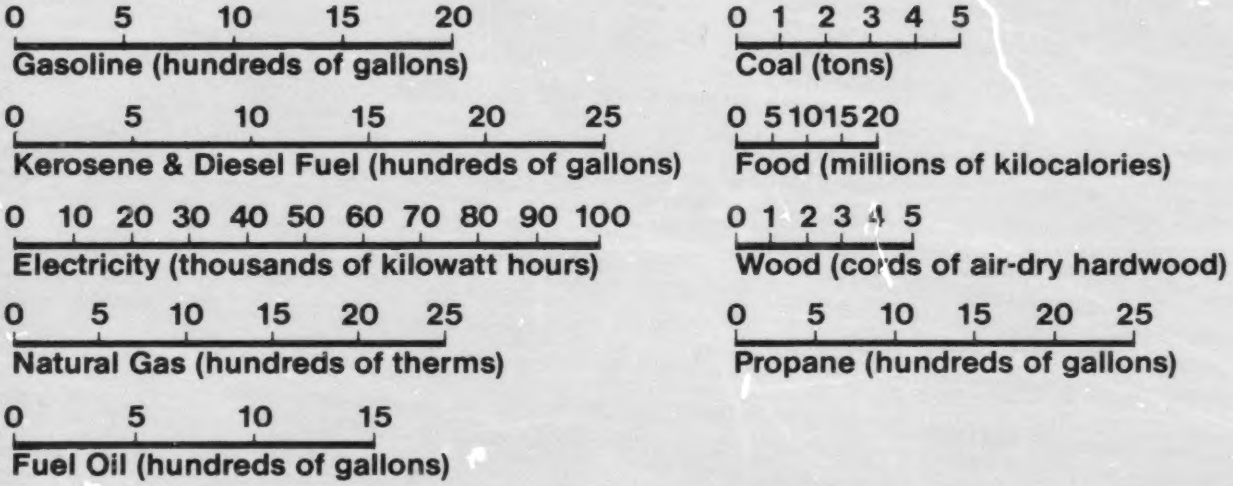
Coal ____________ tons

Kerosene ____________ gallons

Food ____________ kilocalories

Vertical division = 5 million Btu




0 5 10 15 20
Gasoline (hundreds of gallons)
0 5 10 15 20 25
Kerosene & Diesel Fuel (hundreds of gallons)
0 10 20 30 40 50 60 70 80 90 100
Electricity (thousands of kilowatt hours)
0 5 10 15 20 25
Natural Gas (hundreds of therms)
0 5 10 15
Fuel Oil (hundreds of gallons)
0 1 2 3 4 5
Coal (tons)
0 5 10 15 20
Food (millions of kilocalories)
0 1 2 3 4 5
Wood (cords of air-dry hardwood)
0 5 10 15 20 25
Propane (hundreds of gallons)

Unit Seven

Economics and Decision-Making

Narrative Overview

1983 Statement

As with most of the units in this resource book, the following materials are a selection from a planned sequence of lessons and activities. The complete economics sequence will appear in the next edition.

Several considerations guided the choice of this sample. We tried to offer the more fundamental and familiar topics, and to pick lessons that did not rely on a preceding lesson that could not be included. Some lessons were chosen because they were rich in basic data, since teachers already teaching about the economics of energy may have immediate use for this data.

Of the material described in the **Narrative Overview,** the following are included in this sampler:

Section One: Energy as an Economic Problem

The "motivational" first lesson, using the parent's questionnaire, and including the discussion of constant and nominal dollars.

Section Two: Price, Supply and Demand

One set of worksheets, on finding and development costs for petroleum, has been included to show how energy examples can illustrate the operation of economic principles.

Section Three: Economics of Energy Supply

Two simple introductory lessons on the use of the factors of production and the opportunity cost of their use in supplying energy are included. Another lesson on the productivity of capital offers an interesting activity. From the end of the unit, the introductory lesson on external costs (you may be accustomed to calling them social costs) is included.

Section Four: Economics of Energy Conservation

From this section we have taken the lesson on embodied energy, showing that energy costs are incurred in providing most goods and services, and another emphasizing that costs are incurred in conserving energy (a first step toward doing a comparison of costs and benefits).

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We would like to thank the members of the Joint Council on Economic Education network, their national staff, and the energy economists in universities, industry, and government who have generously responded to letters and phone calls, for their encouragement, guidance, and help. In the final edition, this help will be acknowledged more specifically. Robert Highsmith, Clayton Millington, and Clark Bullard deserve a special vote of thanks. Of course, these individuals and organizations are not responsible for the deficiencies that remain, nor do they endorse these materials.

If you might be interested in trial teaching draft versions of other lessons and would like to obtain copies for examination, please contact: Unit Seven Field Test; Energy 80; 1320A Santa Monica Mall; Santa Monica, CA 90401.

Narrative Overview

Why We're Teaching This

No understanding of the human use of energy is complete without the insights provided by economics. How changing circumstances lead us to exploit one energy source instead of another; how money spent now can be compared with money to be saved in the future; who uses energy, and for what purpose—these are the kinds of problems economists study, and such problems are at the root of our energy problems.

In fact, surveys show that it is the wallet aspects of energy that most interest the average person. Students often share their parents' interest, and this creates a teaching opportunity.

Two broad kinds of economic understanding related to energy can be helpful to students:

1. Understanding the economic mechanisms behind events and situations that will affect students indirectly in their adult lives (such as what factors affect the price of energy, and how) can help students be better citizens.

2. Understanding how to apply economic ideas to minimizing their personal energy costs (such as in deciding whether to invest in an energy conservation measure) can help students become energy-smart consumers.

Because they are essential to an understanding of the economics of energy, the unit is forced to present three concepts not usually treated at this grade level:

external costs: Some costs incurred in supplying and using energy are not necessarily borne by the seller (and thus not passed on to the buyer). Health problems caused by air pollution is an example of such a cost. Such costs are not taken into account by market forces in setting prices, and this creates an important dilemma.

marginal cost: At present the average cost of energy is usually much lower than the marginal cost—the cost of supplying one extra gallon of gasoline, or one more kilowatt-hour. This is extremely important because both conservation and production take place at the margin.

present value: After the easy kinds of conservation, like turning out the lights, further conservation requires investment in insulation, more efficient cars, water heaters, or furnaces, and so on. The purchase prices of these items are paid now; but the benefits—like the utility bills avoided—are in the future. The only way of comparing a dollar spent now with a dollar saved in the future is to convert all amounts to their value on the same date, usually the present. To do this requires an understanding of present value.

This unit is not meant as a complete introduction to economics at the junior high school level. It does not treat, for example:

forms of business enterprise
types of economic systems
money
banking
taxes
causes of inflation

—all topics which many economics teachers consider important at this grade level. Instead, it is meant to provide a comprehensive treatment of those topics in economics which are most relevant to energy, building upon the familiarity with energy supply and use which students have gained in preceding units.

What We'll Teach and How

This unit is divided into four sections.

Energy as an Economic Problem

A transition lesson is provided to interest students in learning about the economics of energy. Using a prepared questionnaire, students interview their parents (or another adult), typically learning that the adult is more interested in the price of energy than any other aspect. Recent price and production data are presented as graphs and students are asked to speculate on the causes of the trends seen. The lesson concludes by providing some discussion and homework on the changing value of the dollar. If students do not understand the difference between constant and nominal dollars, long-term price series are not very meaningful.

We then look at the fundamental economic problem of energy: like everything else, useful energy is not so plentiful that people can use it for everything they can think of doing with it. Some way is needed of deciding what we will do and not do with the available energy, and what we are willing to give up and not to give up to get it. Prices help us make these decisions.

This section proceeds by helping the students reorganize, conceptually, information they have already acquired. To simplify presentation of data, numerous masters are provided for the overhead projector.

Price, Supply and Demand

Supply and demand is presented through student experiments that establish the slope of the curves. The lessons first use supply and demand schedules and only later introduce graphing, so that teachers who wish to avoid graphing may do so. The interaction of supply and demand in establishing equilibrium, or market-clearing prices, is then examined.

By examining some historical incidents in the field of energy, students see that the supply or demand curve can shift and what happens to prices when it does.

Ours is a mixed economy and many factors other than supply and demand affect energy prices. Students examine how government actions can affect energy prices in lessons on the regulation of utilities, government subsidies, and price controls. The lesson on price controls is a debate—discussion of controls on natural gas prices, in which students are given information to enable them to assume the roles of different parties in this national debate.

Economics of Energy Supply

The factors of production are introduced and worksheets establish the necessity of using these factors in supplying energy. Through activities, the students examine how one factor can substitute for another, and how people decide whether to invest capital. This process is summarized in a debate-discussion lesson in which students, as directors of an energy firm, debate whether to invest in a synthetic fuel plant.

External costs are introduced in a teacher presentation, and then students are asked to find the external costs in situations described in readings. A second lesson examines the effects of various ways of internalizing such costs. Marginal cost is similarly treated.

Economics of Energy Conservation

This section begins by reminding the students that we consume energy both directly, through purchases of electricity, gasoline, etc; and indirectly, as the energy costs incurred by the suppliers of the goods and services we buy.

We then focus on the costs of saving energy. Ignoring when costs and benefits are received, students perform calculations to compare costs (especially purchase price) and benefits (especially avoided energy costs) in typical consumer situations.

Since a dollar spent now is not equivalent to a dollar to be received in the future, to compare present costs (as for insulation) and future benefits (lower utility bills), we need the idea of present value. After the initial teacher presentation, students use a table to find present values, so that they are not required to solve exponential equations. Using the idea of present value, students compare amounts invested now with energy costs avoided in the future, as they learn a simple form of life-cycle costing.

Energy Is Something People Buy and Sell

Note: A homework assignment that asks students to interview a family member should be completed prior to this lesson.

Why This Lesson?

This lesson is intended to provide a transition from studying the science, technology, and history of energy supply and use to studying the economics of energy. To accomplish this transition, the lesson attempts to motivate student interest in economics by demonstrating that the aspects of energy which seems to be of most interest to students and their family members are exactly those aspects which are addressed by economics.

Objectives

As a result of this lesson, students will:

Be able to describe the trend of energy prices in the period 1930 to 1980

Be aware of their interest in the economic aspects of energy supply and use

Be able to describe generally what economics is about

Be able to describe the difference between real and nominal prices

Format of the Lesson

(Assign interviews of parent for completion prior to lesson)

Tally interviews: Have energy prices risen?

Use overhead transparancies to review energy price trends

Tally interviews: Do changes in prices affect what people do?

Use overhead transparencies to examine other economic activity related to energy prices; have students speculate on relationships

Tally interviews: What aspect of the energy problem are people most interested in?

Discussion: What is economics about?

Sublesson: Real and nominal prices (use overheads to establish that nominal prices are not the whole story)

Materials Needed

Interview form **Questionnaire,** one per student.

overhead projector

transparency **Service Station Price of Gasoline**

transparency **Average Price of Electricity Sold to Homes.**

transparency **Average Price of Bituminous Coal**

transparency **Drilling Trends.**

transparency **Solar Collector Production.**

transparency **Wood Stove and Fireplace Insert Sales.**

transparency **Number of Hours of Labor Needed to Buy a 15-Gallon Tank of Gasoline.**

transparency **Number of Hours of Labor Needed to Buy 100 kWh of Electricity.**

For the Sublesson

reference sheet **How Much Would It Take to Buy What a Dollar Would Buy in 1980?**, one per student.

worksheet **Real and Nominal Dollars,** one per student.

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Pre-Lesson Assignment

About a week prior to the first economics lesson, give students the activity sheet called **Questionnaire.** Ask them to complete it as homework, interviewing a family member, if possible. Go over the interviewing technique in class covering the following points:

- Read the question and answers to the person being interviewed.
- Before asking the first three questions, read the introductory paragraph. Be sure the person interviewed understands the scale.
- Make notes on a separate sheet of paper.

In some classes, it may be helpful to have two students role-play an interview as an demonstration.

CONDUCTING THE LESSON

Discussing the Interviews

Ask students to look at the questionnaire and their notes. Let's begin with Questions 5, 6, and 7. What are these three questions about? What have they in common? (ANS: All are about whether prices of different sources of energy have risen.)

On the chalkboard, write "5" and under it makes 3 column headings: "cheaper," "more expensive," "about the same." By a show of hands, have students indicate which response the person they interviewed gave. Fill in the totals on the chalkboard. Do the same for Questions 6 and 7.

What can we conclude? Do people think prices are higher than when they were young? (ANS: The results are likely to show that people do think energy prices have increased.)

Is this true? Are the people who were interviewed right? Let's look at some historical records.

Looking at Some Historical Data

Gasoline Price Graph

Using the overhead projector, show the graph of gasoline prices. Ask a student to describe how the price of gasoline changed between 1920 and 1980. Did the price of gasoline increase? Was it a slow, steady increase or did it increase in jumps? (ANS: Big jump in 1974, a small jump in 1980.)

What might have made the price suddenly go up in the 1970s? What reasons did the people interviewed give, in question 13? Why do *you* think the price went up?

At this point, our goal is to provoke student interest in the questions, and to bring out a variety of opinions and possibilities. Many responses will be naive, of course. At this point, avoid endorsing or rejecting explanations which the students offer. You're probably aware, as are many students, that the price increases in 1974 and 1979 were related to wars, revolutions, and actions taken by the OPEC cartel. Such background information should not be introduced by you at this time; later there will be opportunities to discuss all these questions in a less simplistic way than would be necessary if they were treated now.

Electricity Price Graph

Project the graph of electricity prices. Ask a student to describe how the price of electricity changed between 1910 and 1980.

What happened to prices between 1900 and 1970? (ANS: They went down.) Why did they go down?

What might have caused electricity prices to begin to go up? What ideas did the people interviewed have, in responding to question 14? What are *your* ideas?

Could there be any connection between the rise in the price of gasoline and the rise in the price of electricity?

(Background information: The long-term price decline was related to the increasing efficiency of the generating equipment, among other factors. A plateau in efficiency improvements was reached in the 1960s. Petroleum and natural gas are burned to generate some electricity (as can be seen from the energy flow graph on page 26 and 27 of the student booklet); increases in the cost of fuel increased the cost of electricity. Skyrocketing construction costs inflated the fixed costs of new power plants. Also, as the price of petroleum rose, it became more economical to substitute electricity in a few applications, e.g., in some residences.)

Coal Prices Graph

(Skip over this graph if there is a time pressure in your class.)

Project the graph of the price of bituminous coal. Ask a student to describe how the price of coal changed. Is there any connection between what happened to the price of coal and what happened to the prices shown in the other two graphs?

(Background information: The cause of the recent rise in the price of coal is somewhat controversial. Important factors include: Substitutes (i.e., petroleum), became more expensive. The cost of extracting coal increased owing to new legislation that required mining companies to bear the costs of new reclamation and safety measures.)

Summarizing Recent Price Trends

Summarize for the class that, as we have seen, in the recent past energy prices have increased, in some cases after going down for years. Many different ideas have been expressed about why prices have changed but it isn't obvious whether any of these ideas are correct.

How Do Prices Affect People's Decisions?

Let's go on by looking at another kind of question about energy. Do you think that increasing or decreasing energy prices could affect how people use energy? Did the people you interviewed think so?

Look at questionnaire question 4. Call for a show of hands for "more," "less," "about the same," and "don't know," and record the totals on the chalkboard. Probably, the people interviewed will feel their use of energy has increased.

Do a chalkboard tally or histogram for questions 9 and 11. Do changes in the price of gasoline change people's decisions? How? Why? Ask students to read some individual responses from their notes on their interviews.

Do a chalkboard tally or histogram for questions 10 and 12. How are these answers like the answers to the gasoline questions?

Conclude that changes in prices do affect people's decisions about how much energy they will use, and for what.

Effects of the 1970s Price Increases?

Instead of looking at individuals, let's now look at some things whole groups of people did during the last ten years or so.

Supply of Natural Gas

Project **Marketed Production of Natural Gas.** What happened? What might be some reasonable explanations of why less gas was sold in 1975 than in 1970? How could we test these explanations?

Drilling Activity Graph

Project the graph of drilling activity. Explain that this graph shows *changes* in two quantities: the numbers of wells drilled in a year in the United States, and the price of crude oil in the United States. But it does not show the actual price or the actual number of wells. Instead, it uses **index numbers.** The value in one year, 1967, is taken to be 100. Every other year is compared to 1967. What would an index number of 200 for wells drilled in the year 1990 mean? (ANS: It would mean that twice as many wells were drilled in 1990 as in 1967.)

Ask a student to describe how the price of oil changed. Ask another student to describe changes in the number of wells drilled per year. Why the big increase in drilling?

Solar Collector Production Graph

Project the graph of solar collector production. If your class has not studied Unit Five, you may need to explain the meaning of "square feet of solar collectors." All solar collectors have surfaces exposed to the sun; the amount of energy a solar collector can gather is limited by the surface area. So, a useful way of keeping statistics on production of all the various kinds of solar collectors is to add their surface areas.

What does the graph show? Why might production of collectors have increased.

Wood Stove Sales Graph

Show the graph of the sales of wood stoves. Ask a student to describe how the number of stoves sold changed.

Why are sales of woodstoves increasing? Is there any connection between the change shown in this graph and the changes shown in any of the other graphs?

Tell the students that the kinds of suggestions of relationships they're making belong to a discipline called **economics.** In trying to relate prices and what people decide to do, they are acting like **economists.**

Are People Interested in Economics?

Do a chalkboard tally of the responses to Questions 1 through 3, using a format like that on the Teacher Tally Sheet. Ask students to summarize the results. What are people most interested in?

Now tally the responses to Question 15. They will probably show that high costs are most often voted the leading problem.

What does this show? It shows that people are very interested in the kinds of subjects economists study, like why prices rise.

We have been studying the history of energy, how we get energy and how we use it. Now, to help us understand why people decide to get and use energy the way they do, we will study the economics of energy.

Sublesson: Inflation

Teacher Background

In studying energy it is very helpful to be able to look at how prices have changed over a long period of time, as we just have. Unfortunately, these changes are obscured by changes in the buying power of a dollar. To remove this "noise," economists often use "constant" dollars. Seriously consider teaching a lesson on real and nominal prices, in order to be able to use this tool in class discussions.

Introducing the Topic

Ask students to look at question 8 of the interview. Not only energy prices have changed. Wages have changed too. The value of a dollar — which is what you can buy with it — may change from year to year.

Project again the transparency **Service Station Price of Gasoline.** Ask students to try to remember the trend of the price. Now project the transparency titled "Hours of Work..." Explain to the class that this graph is constructed from two types of information: the average hourly wage of all the workers in manufacturing in a particular year, and the price of ten gallons of gasoline (including tax) in that year. The graph shows how many hours the average worker had to work to get a tank of gas. Ask a student to describe the changes shown by the graph. Did the price of gasoline, in terms of the worker's buying power, show a steady rise? How does the information in this graph add to the information in the graph of the service station price of gasoline?

Conclude that in order to compare changing *prices*, we need to be able to compare *dollars* in different years. A dollar in 1950 would buy more than a dollar will today. To compare prices in different years, economists need a dollar with about the same buying power in every year. They call this a "constant dollar" or a "real dollar." Constant dollars are a form of **index number,** like the ones we saw in the graph of drilling activity. They must refer to a particular year in which a dollar was worth a dollar; that is, one constant dollar was equal to one "nominal dollar," the dollars on price tags that year.

Project the graph **Natural Gas Wellhead Price.** This shows the price in cents per thousand cubic feet. The constant dollars price is in 1972 cents. Look at what happens after 1975. The price in constant dollars didn't increase as much as the price in nominal dollars, because the dollar was worth less. (But, if all the increase in gas prices had been due to inflation, the constant dollar line would not have gone up at all.)

Homework

Pass out the reference sheet **How Much Would It Take to Buy What a Dollar Would Buy In 1980?**

Ask students to find 1980 on the sheet. Point out that in 1980 a dollar was worth 1.00 1980 dollars. Now find 1960. In 1960, 0.359 dollars could buy what one dollar would buy in 1980. Could one dollar buy more in 1980 or in 1960?

In recent years, the value of the dollar has been falling. Can anyone find in the table some years in which the value of the dollar rose?

If we wanted to say how many 1980 dollars a 1960 dollar was worth, we can divide. 1.00 divided by .359 = 2.79 (rounded off to the nearest cent). So a 1960 dollar is worth 2.79 1980 dollars.

Using a table like this, we can make a rough comparison of prices in different years.

Pass out the worksheet **Real and Nominal Dollars**. Read the introductory paragraphs in class. Perhaps work some of the examples in class, assigning the remainder as homework.

Answers to the worksheet **Real and Nominal Dollars**

1. The answer depends on the amount of the respective allowances and the parents' ages.

2. In 1980 dollars, the 1980 ticket costs $2.50. The 1960 ticket costs $4.18 in 1980 dollars ($1.50 divided by .359 equals 4.18, rounded off). So the ticket was more expensive in 1960.

3. They went up.

4. The 1950 car ($2,300 divided by .282 = $7,887).

5. Let's convert both wage rates to 1980 dollars.
   — $.19 divided by .109 equals 1.74 (1980 dollars).
   — $5.69 divided by .881 equals $6.46 (1980 dollars).
   — So the worker in 1979 made *a lot* more.

6. Let's convert both prices to 1980 dollars.
   — $11.80 divided by .598 equals $19.73 (1980 dollars).
   — $14.10 divided by .881 equals $16.00 (1980 dollars).
   — So Abu Dhabi was getting more for its oil in January 1974. (And that was one of the motivations for the 1979 second round of price increases, reflected in the next question.)

7. Convert both prices to 1980 dollars.
   — 40.41¢ divided by .598 equals 67.58¢ (1980 cents).
   — 73.28¢ divided by .881 equals 84.43¢ (1980 cents).
   — So gasoline was cheaper in 1974.

8. $0.162 divided by .105 equals $1.54 a kilowatt-hour. (Still cheaper than flashlight batteries today!)
   — 2.09¢ divided by .445 equals 4.7¢, which is cheaper than 4.93 cents, so the price rose.

9. — $6.20 divided by .105 equals 59.05.
   — $30.20 divided by .471 equals 64.12.
   — So wholesale beef was cheaper in 1902.

10. Depends on item chosen by student.

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Lesson
continues.

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Teacher's Tally Sheet for Questionnaires

1. 1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____ 7 ____ 8 ____ 9 ____ 10 ____

2. 1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____ 7 ____ 8 ____ 9 ____ 10 ____

3. 1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____ 7 ____ 8 ____ 9 ____ 10 ____

4. Comparing uses, now and then
less ____________
about the same ____________
don't know ____________

5. Electricity
cheaper ____________
more expensive ____________
about the same ____________

6. Gasoline
cheaper ____________
more expensive ____________
about the same ____________

7. Natural Gas
cheaper ____________
more expensive ____________
about the same ____________

8. Wages when in high school
more ____________
less ____________
about the same ____________

9. New car
bigger ____________
smaller ____________
the same size ____________

10. Use more or less electricity than 10 years ago
more ____________
less ____________
about the same ____________

11. If the price of gas rose . . .
carpool ____________
use bus for work, shopping ____________
cut down on driving for pleasure ____________
buy a new car ____________

12. If the price of electricity fell . . .

13. Why gasoline prices went up . . .
OPEC ____________
greed of big oil companies ____________
oil is getting harder to find ____________
more people want oil ____________
higher taxes ____________
everything is getting more expensive ____________

14. Why electrical rates went up . . .
fuel is more expensive ____________
everything else has gone up ____________
utilities are greedy ____________
it costs more to build power plants ____________

15. Nature of energy problem

		ONE	TWO	THREE
it costs too much				
pollution				
not available				

Questionnaire

Using the questions below, interview someone. Try to interview a person who is at least forty years old; the older the better. It is best if you interview a relative such as one of your grandparents, one of your parents, an aunt or an uncle, but, if necessary, you may interview a neighbor or teacher instead.

Tell the person you will inteview that the interview will take about half an hour. Try to do the interview at a time when you will not be interrupted. Before beginning the interview, *tell the person that you will not be writing down his or her name.*

Read the questions one at a time to the interviewee. Check the answer. You may need to check more than one answer. On a separate piece of paper, write notes on his or her answers to the "why?" questions.

This is an interview about energy. We buy energy when we buy electricity, gasoline, coal, natural gas, or firewood.

First I will ask some questions about how you feel about energy. Rate your feelings on a scale of one to ten. Ten means you care a lot. One means you don't care at all.

Circle the person's response.

										Not at all
1. *Do you care where energy comes from?*	10	9	8	7	6	5	4	3	2	1
2. *Do you care how we get energy?*	10	9	8	7	6	5	4	3	2	1
3. *Do you care how much energy costs?*	10	9	8	7	6	5	4	3	2	1

4. *When you were my age, did your family use about as much energy as your family does not? If there is a difference, why?*	more energy less energy about the same don't know

Make notes of answer(s) to the "why?" question.

5. *When you were my age, was electricity cheaper or more expensive than it is now?*	cheaper more expensive about the same
6. *When you were my age, was gasoline cheaper or more expensive than it is now?*	cheaper more expensive about the same
7. *When you were my age, was natural gas cheaper or more expensive than it is now?*	cheaper more expensive about the same
8. *When you were in high school, did people earn more or less money than they do now?*	more less about the same

9. (Ask only if the person owns a car) *If you were going to buy a new car, would you buy one about the same size, bigger, or smaller than the one you now have? Why?*

bigger
smaller
the same size

10. *Do you think you use more or less electricity than you did ten years ago?*

more
less
about the same

11. *If the price of gasoline rose to $5 a gallon, would you do anything differently from the way you do it now?*

carpool
use bus for work, shopping
cut down on driving for pleasure
buy a new car

Make notes on any other answers the interviewee gives.

12. *If electricity became a lot cheaper, say one-tenth as much as it is now, would you do anything differently from the way you do it now?*

Make notes.

13. *Why have gasoline prices gone up?*

OPEC
greed of big oil companies
oil is getting harder to find
more people want oil
higher taxes
everything is getting more expensive

Make notes on any other answers the interviewee gives.

14. *Why have electricity prices gone up?*

fuel is more expensive
everything else has gone up
utilities are greedy
it costs more to build power plants

Make notes on any other answers the interviewee gives.

15. *Some people think we have an energy problem. I'll read three things people have thought of as a problem. Please tell me which of the three you think is the biggest problem.*

it costs too much
pollution from getting and using energy
we may not be able to get it when we need it

Mark this answer "1."

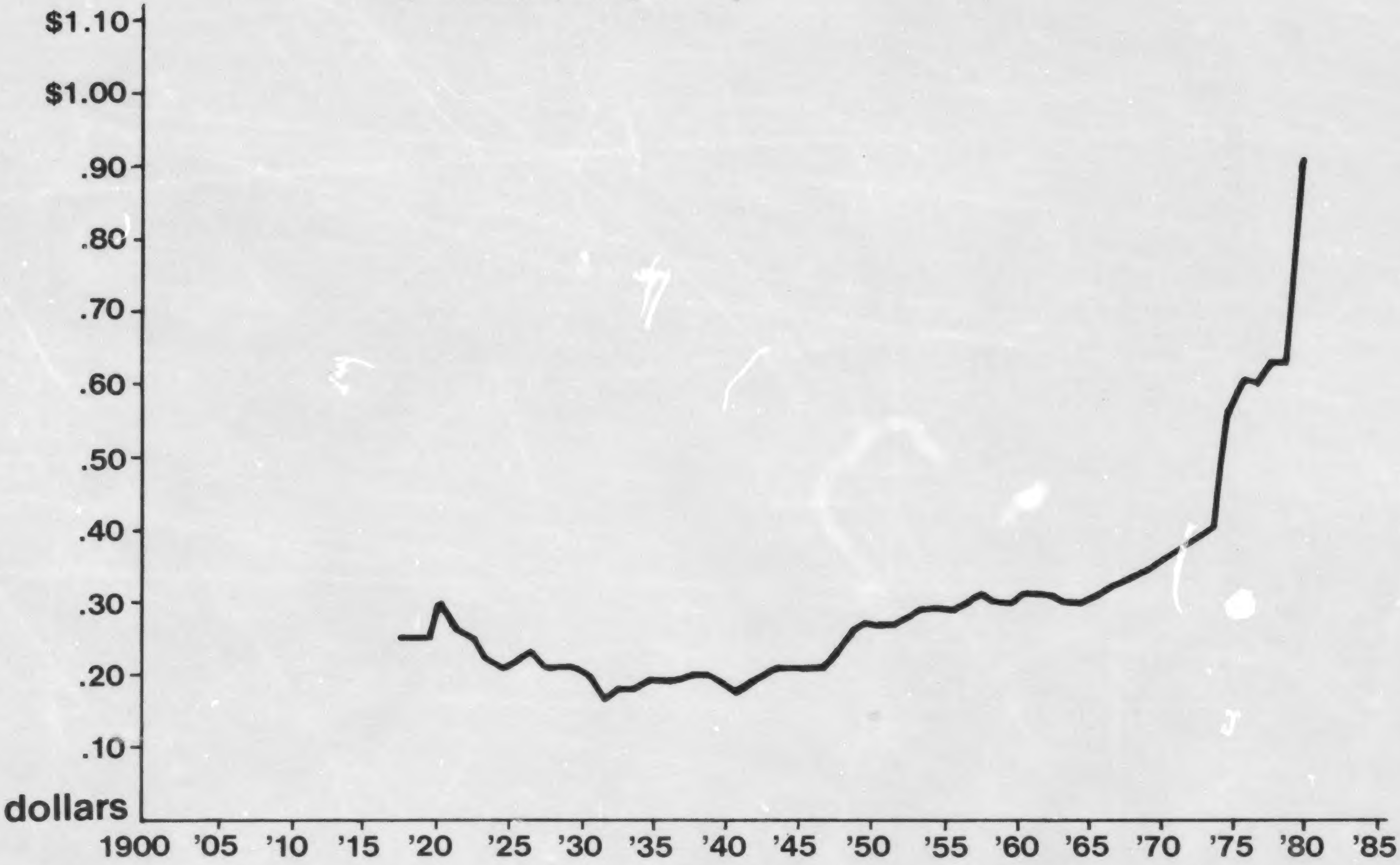
Of the three, which do you feel is the least important problem?

Mark this answer "2."

Be sure to thank the person you have interviewed for helping you with your homework.

Service Station Price of Gasoline

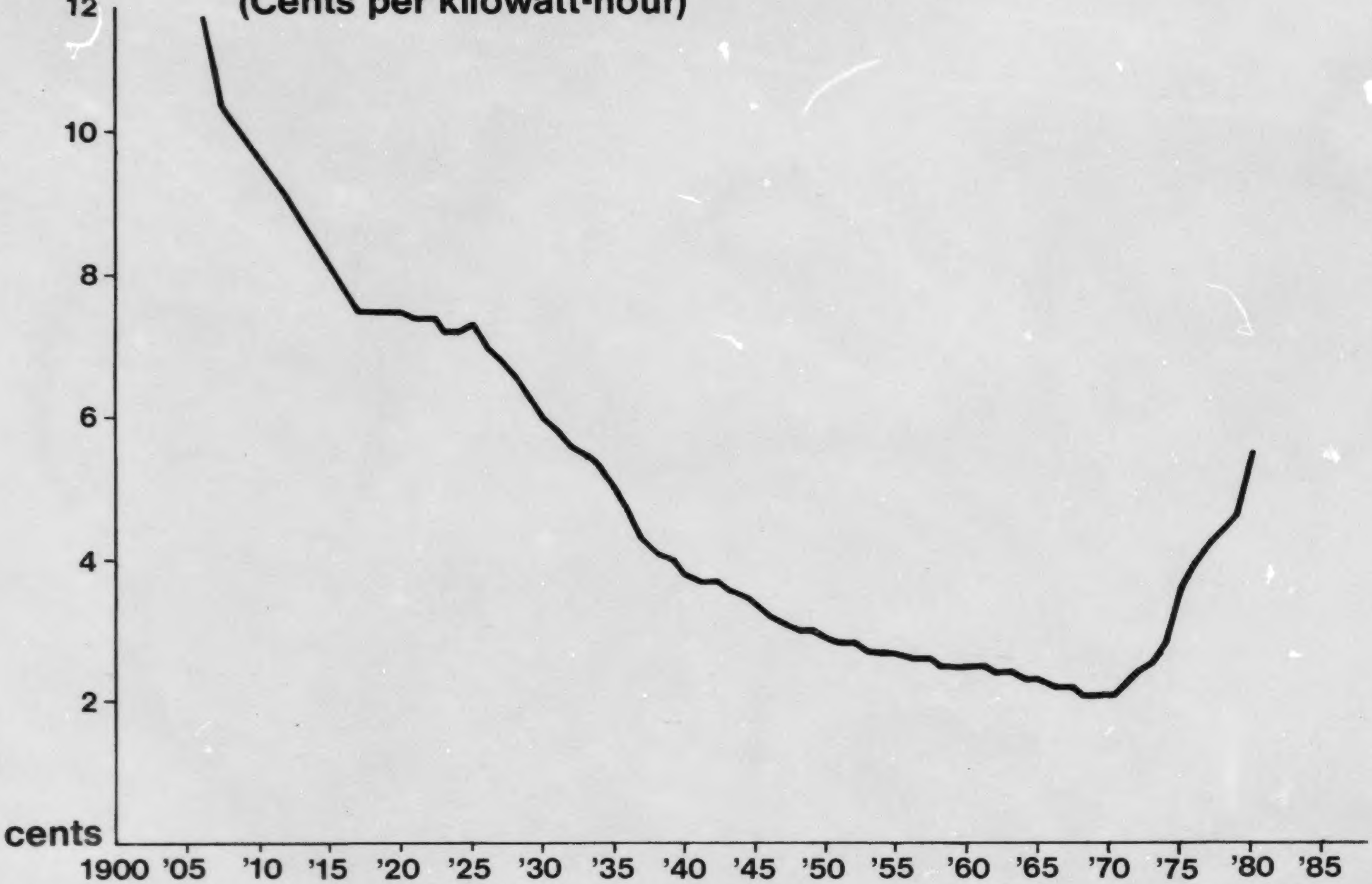
(Dollars per gallon)



Source: 1918-1969: **Petroleum Facts and Figures.** American Petroleum Institute. Port City Press; Baltimore, MD. 1971. 1970-1979: Regular grade. **Statistical Abstract of the United States.** 1980. Table 1111.

Average Price of Electricity Sold to Homes

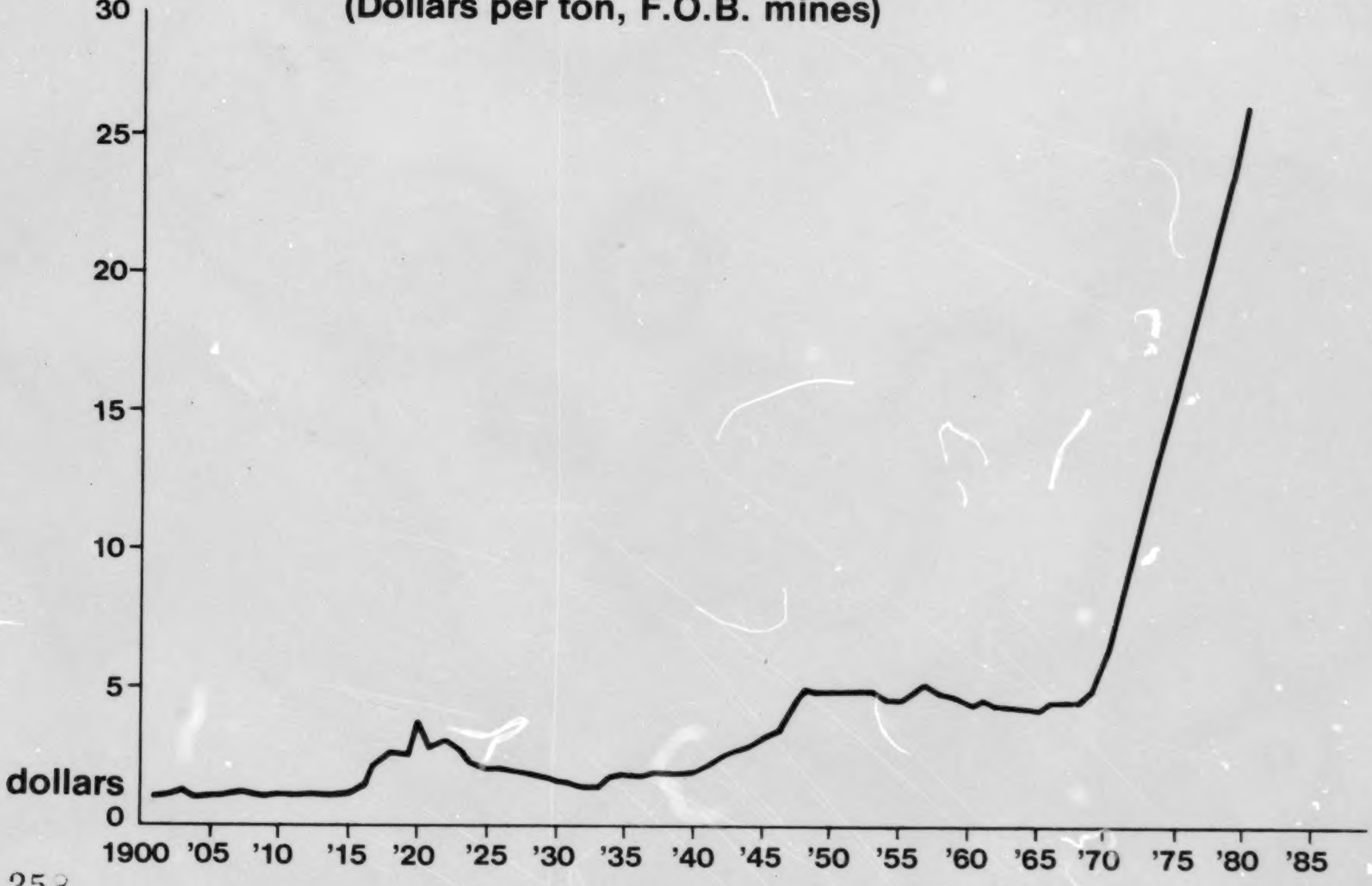
(Cents per kilowatt-hour)



Source: 1902-1970, U.S. Bureau of the Census, **Historical Statistics of the United States. Bicentennial Edition.** 1975. Series S-116. 1971-77: For consumers of 500 kHh/month. U.S. Bureau of Census. **Statistical Abstract of the United States.** 1981. Table 807.

Average Price of Bituminous Coal

(Dollars per ton, F.O.B. mines)



Source: 1900-1969: **Historical Statistics of the United States.** Series M-96. 1970-1976: **Statistical Abstract of the United States.** 1980. Table 1326.

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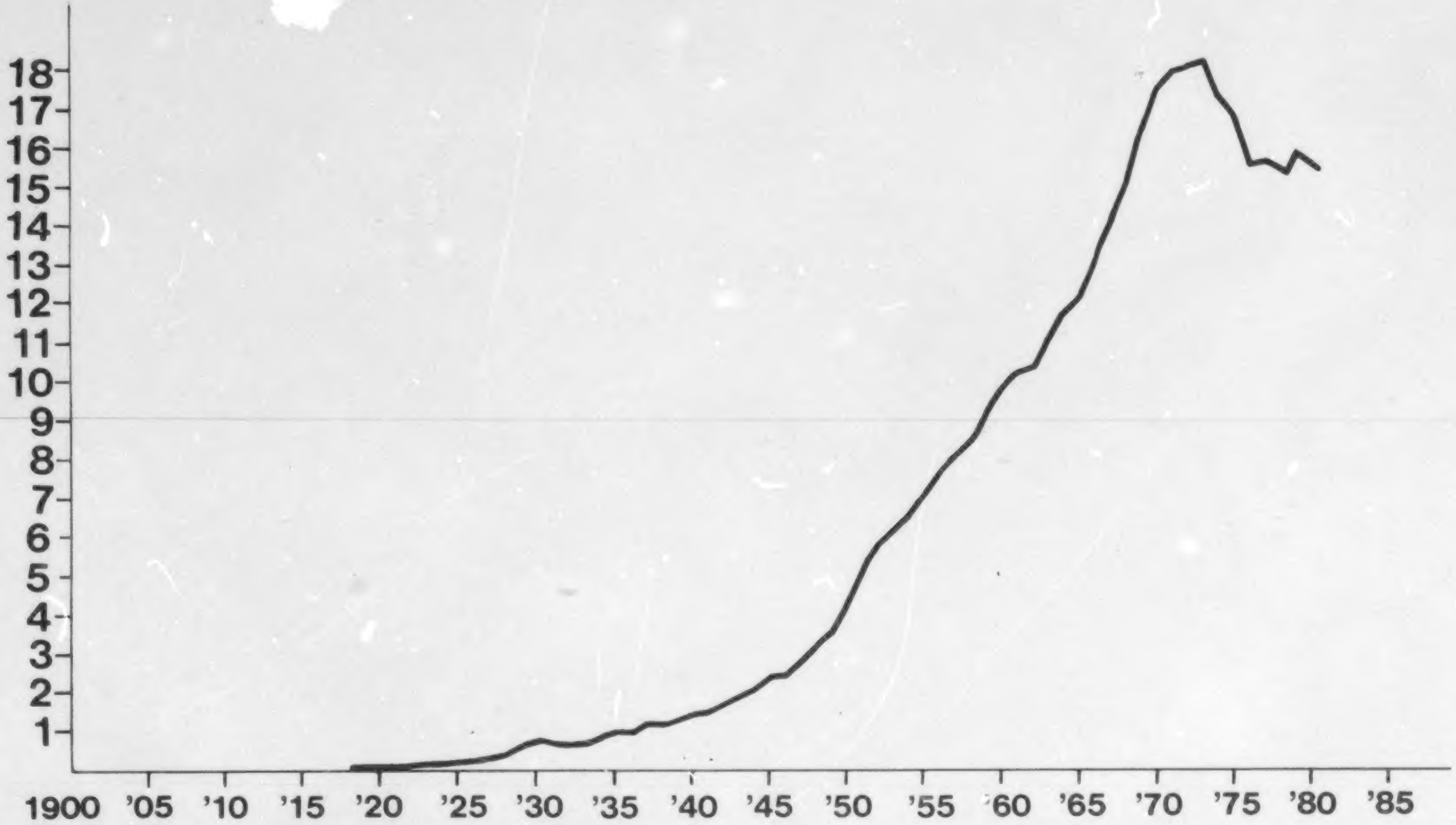
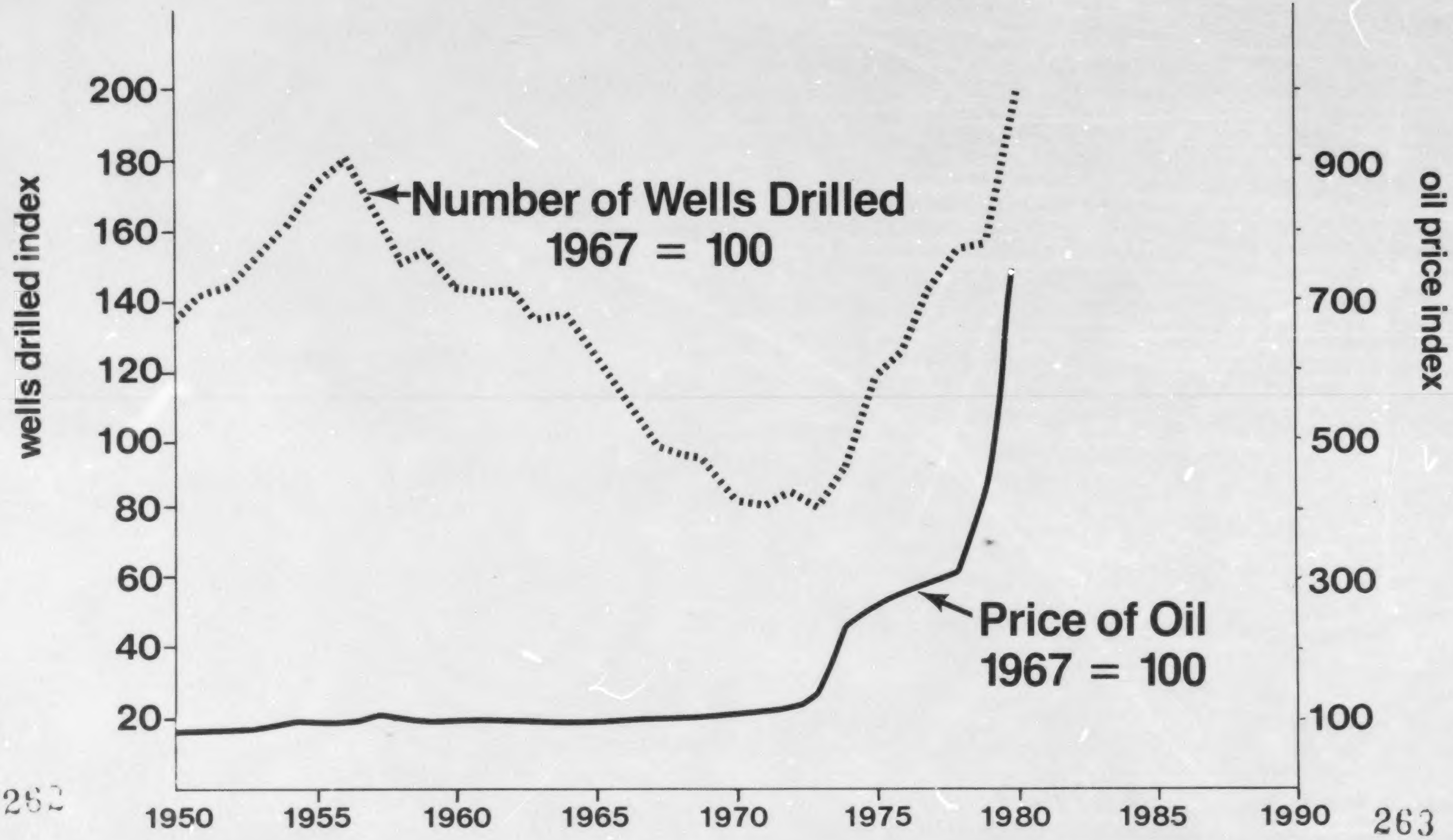
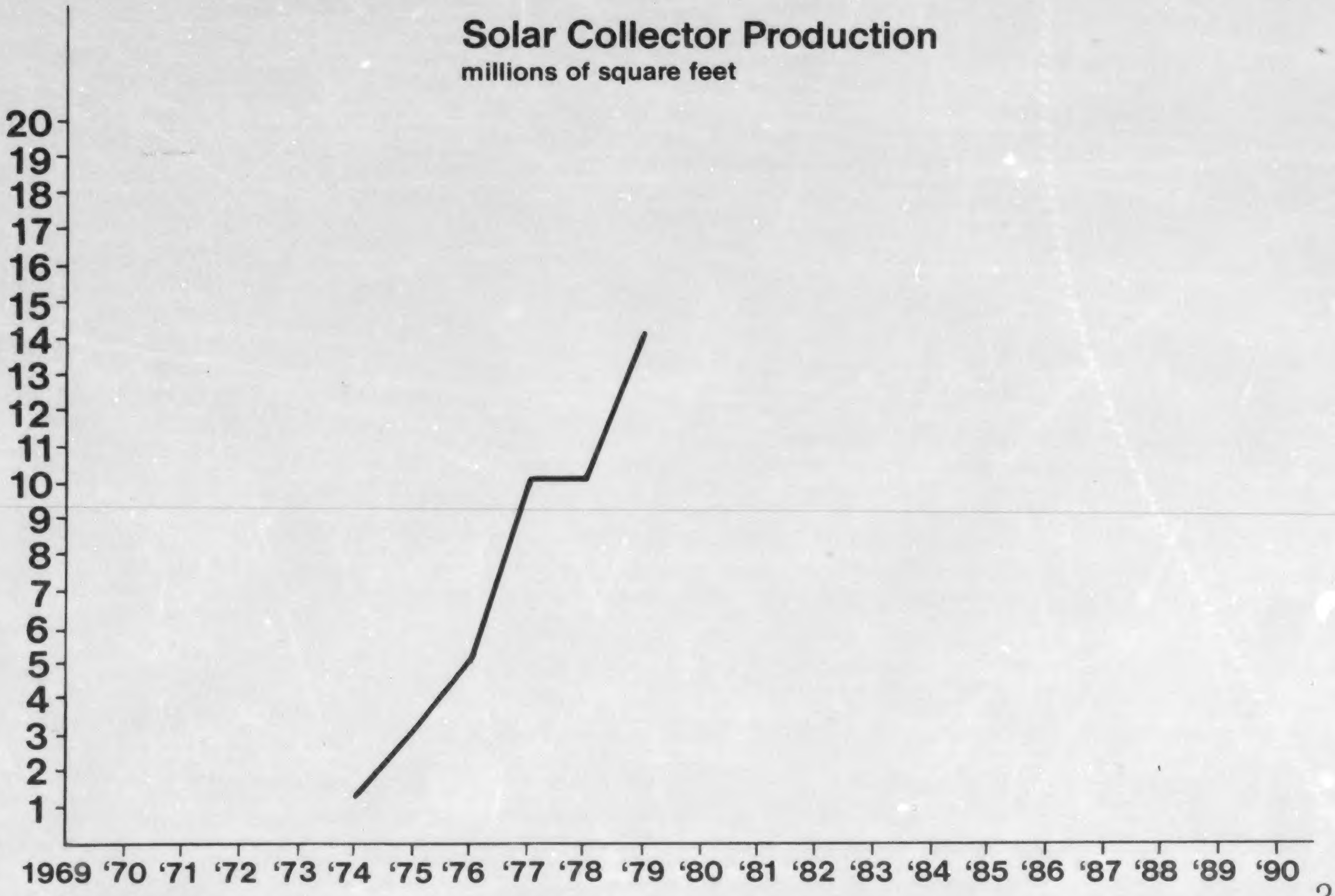
Marketed Production of Natural Gas

(Billions of cubic feet)



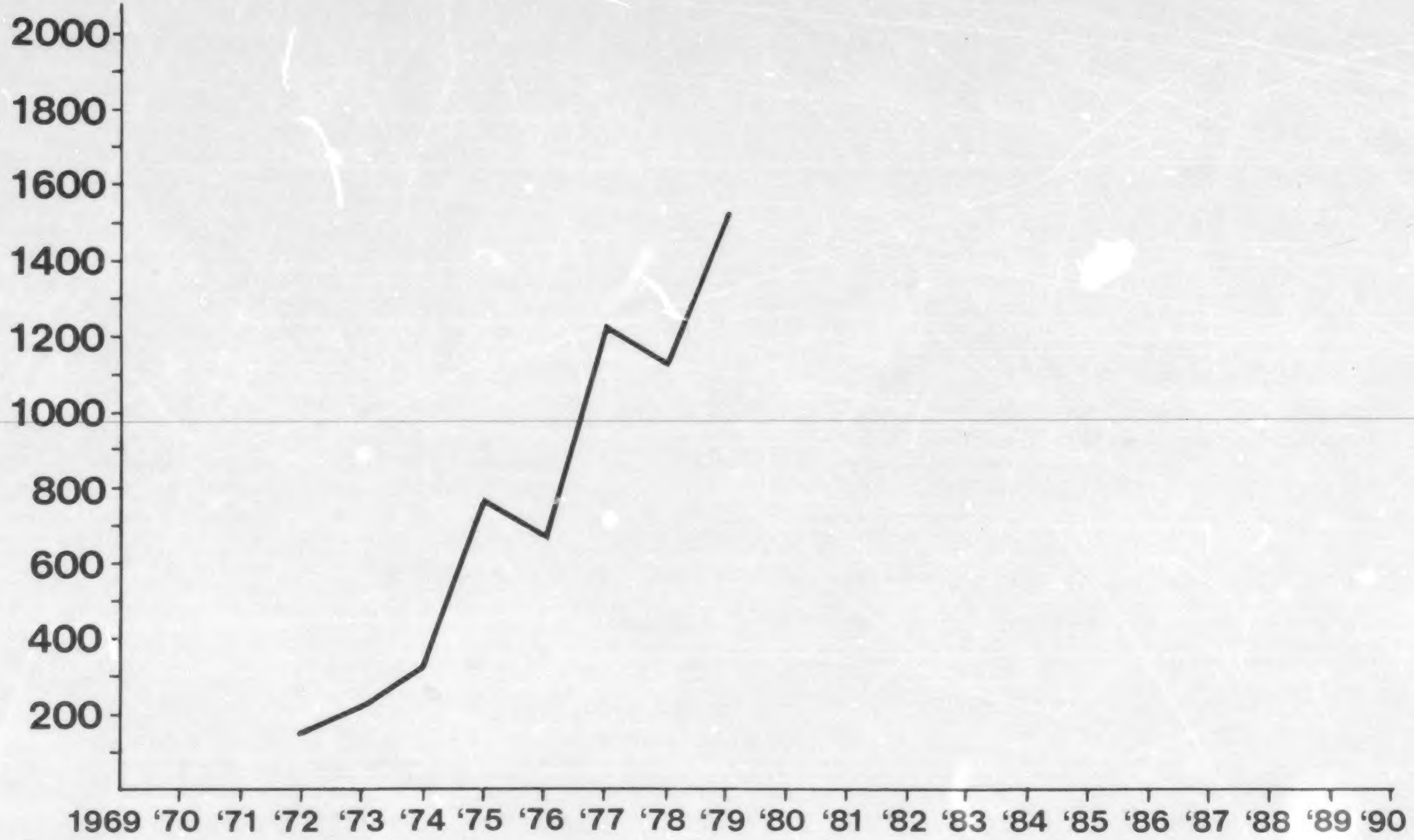
Comparison of Drilling Activity & Oil Prices in the United States



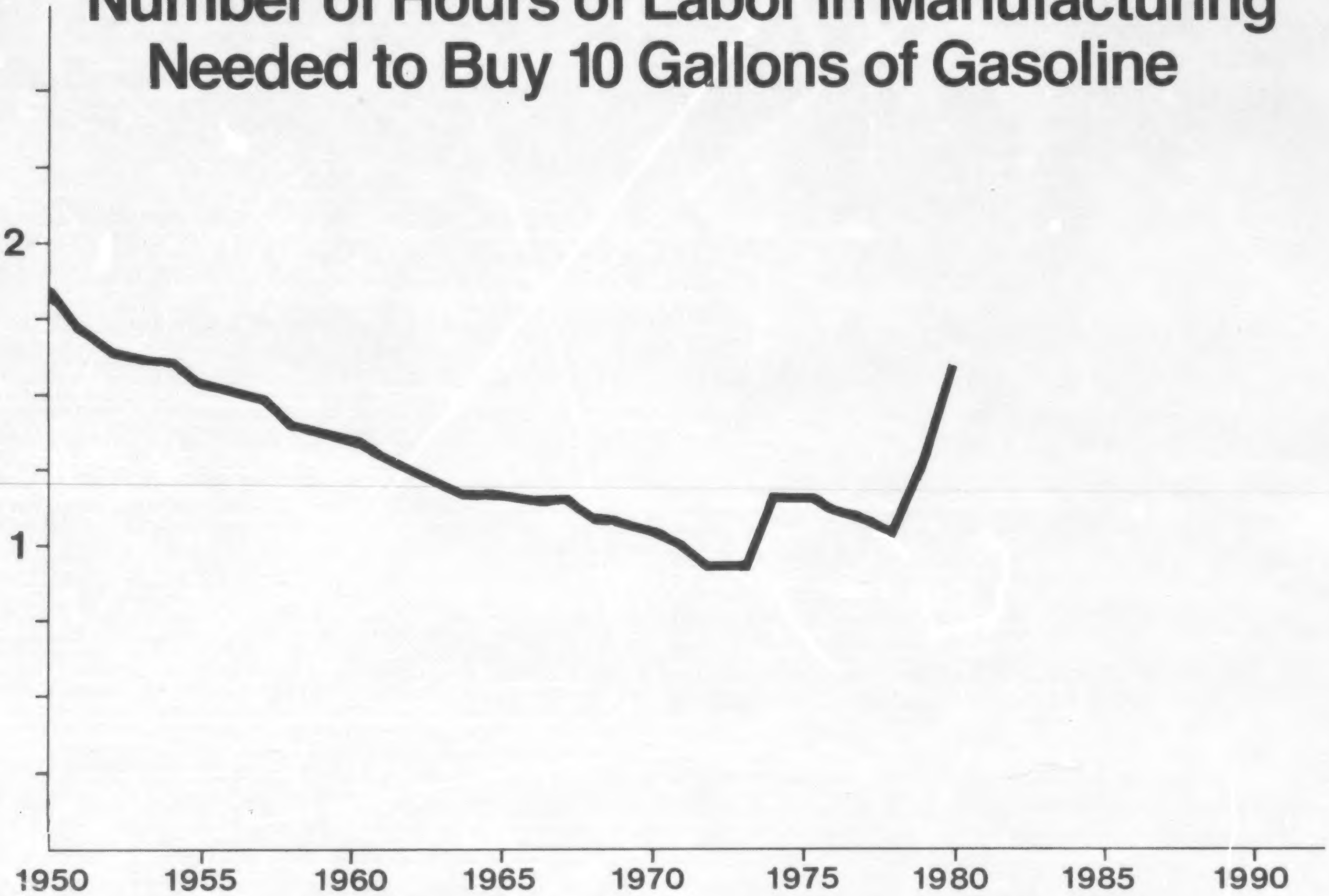

Solar Collector Production
millions of square feet
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1969
'70
'71
'72
'73
'74
'75
'76
'77
'78
'79
'80
'81
'82
'83
'84
'85
'86
'87
'88
'89
'90

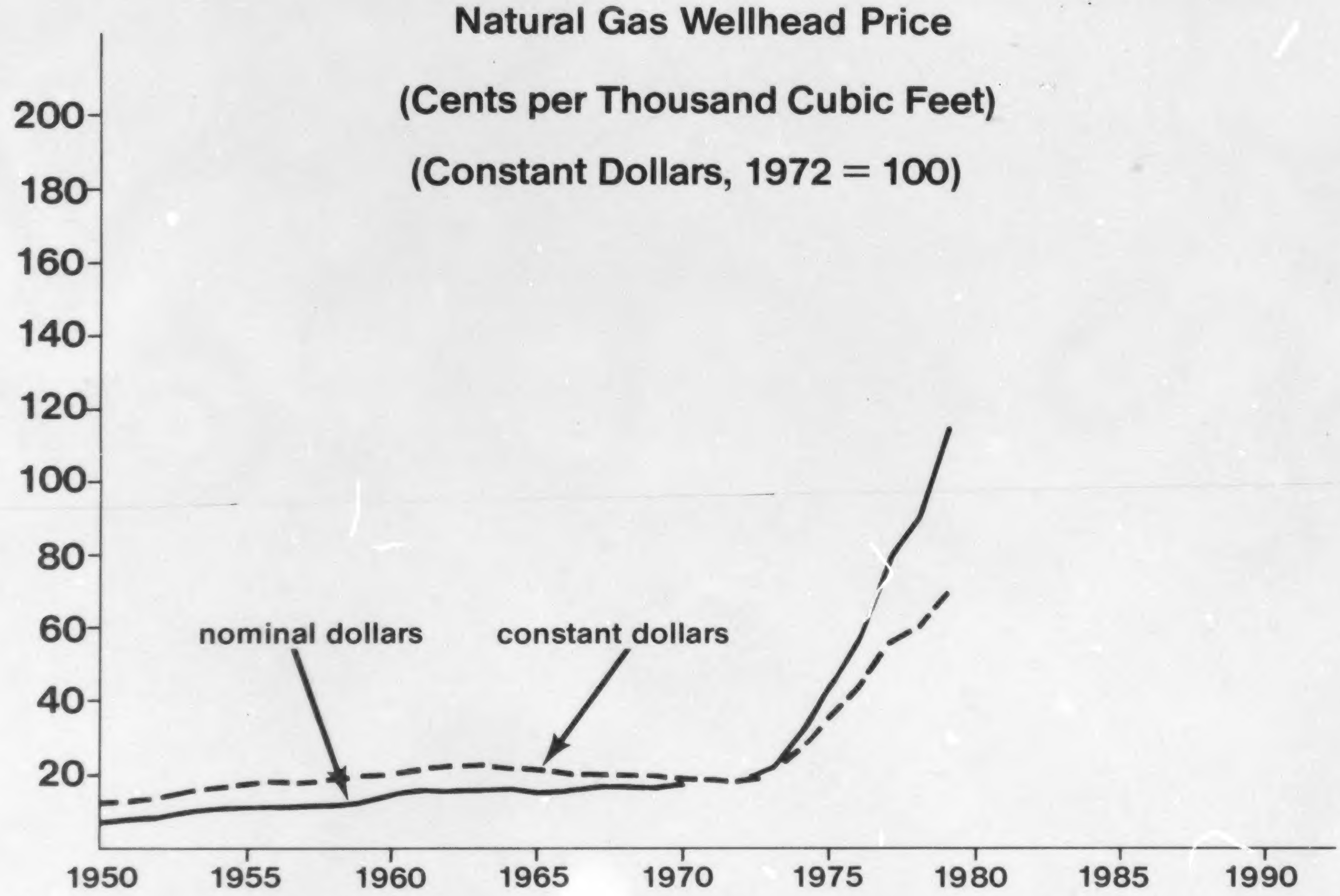
Wood Stove & Fireplace Insert Sales

(Thousands of units sold)



Number of Hours of Labor in Manufacturing Needed to Buy 10 Gallons of Gasoline





Natural Gas Wellhead Price

(Cents per Thousand Cubic Feet)

(Constant Dollars, 1972 = 100)

Real and Normal Dollars

Because of inflation (and, sometimes, deflation), a dollar may buy more in one year than it will in another. However, economists often want to compare prices in different years. One way of doing this is to compare the prices of goods with the amount of time an average worker would have to work to buy those goods, or to compare the price of a bundle of different goods and services.

Economists call the dollars on price tags **nominal** or **current** dollars. When the dollars are corrected for inflation so that prices in different years can be compared, they call them **real** or **constant** dollars. All **real** or **constant** dollar figures must have a year to which they refer. Usually, in that year the dollar is said to be worth 100. All other years are compared to that year.

You have been given a table which you can use to compare prices in different years. For each year, it shows what part of a dollar would be needed to buy what one dollar would buy in 1980.

For example, a student who got an allowance of $1 a week in 1980 could buy about as much with it as a student could buy in 1950 with an allowance of 29¢ a week.

To compare prices in different years, convert both prices to 1980 dollars. Do this by dividing the price by the number in the table. For example, an item that cost $3.75 in 1972 would cost (3.75 divided by .508 =) $7.38 in 1980 dollars.

Now do the problems below.

1. If you get an allowance from your parents, is it more or less than the allowance they got when they were your age after you correct for inflation?

2. In 1960, you could buy a movie ticket for $1.50. Today a ticket at the same theater costs $2.50. In real dollars, has the price of the ticket gone up or down?

3. What happened to prices during the Civil War (1861 to 1865)?

4. In 1950, you could buy a good medium-sized car for $2,300. In 1980, a car that size cost $10,000. In constant dollars, which cost more?

5. The average hourly wage of factory workers in 1909 was 19¢ an hour; in 1979 it was $5.69 an hour. Who was paid more in real dollars?

6. In January 1974, Abu Dhabi got $11.80 a barrel for its oil. In January 1979, it received $14.01 a barrel. In real dollars, was it getting more for its oil in 1974 or in 1979?

7. In 1974, the typical pump price of gasoline (not including taxes) was 40.41¢; in 1979 it was 74.38¢ per gallon. In real dollars, was gasoline cheaper in 1974 or 1979?

8. In 1902, electricity sold for 16.2¢ per kilowatt-hour. How much would that be in 1980 dollars?

9. In 1969, the average residential price was 2.09¢ per kWh; in 1980 it was 4.93¢. In constant dollars, which was greater?

10. From an older person in your house get any price you like that that person remembers from when they were your age, and convert that price to 1980 dollars.

How Much Would It Take to Buy What a Dollar Would Buy in 1980?

1980	1.000
1979	.881
1978	.792
1977	.735
1976	.691
1975	.653
1974	.598
1973	.539
1972	.508
1971	.492
1970	.471
1969	.445
1968	.422
1967	.405
1966	.394
1965	.382
1964	.376
1963	.372
1962	.367
1961	.363
1960	.359
1959	.354
1958	.351
1957	.342
1956	.330
1955	.325
1954	.326
1953	.325
1952	.322
1951	.315
1950	.292
1949	.289
1948	.292
1947	.271
1946	.237
1945	.218
1944	.214
1943	.210
1942	.198
1941	.179
1940	.170
1939	.169
1938	.171
1937	.174
1936	.168
1935	.167
1834	.163
1933	.157
1932	.166
1931	.185
1930	.203
1929	.208
1928	.208
1927	.211
1926	.215
1925	.213
1924	.208
1923	.207
1922	.203
1921	.217
1920	.243
1919	.210
1918	.183
1917	.156
1916	.133
1915	.123
1914	.122
1913	.120
1912	.118
1911	.114
1910	.114
1909	.109
1908	.109
1907	.114
1906	.109
1905	.109
1904	.109
1903	.109
1902	.105
1901	.101
1900	.101
1899	.101
1898	.101
1897	.101
1896	.101
1895	.101
1894	.105
1893	.109
1892	.109
1891	.109
1890	.109
1889	.109
1888	.109
1887	.109
1886	.109
1885	.109
1884	.109
1883	.114
1882	.118
1881	.118
1880	.118
1879	.114
1878	.118
1877	.130
1876	.130
1875	.134
1874	.138
1873	.146
1872	.146
1871	.146
1870	.154
1869	.162
1868	.162
1867	.170
1866	.178
1865	.186
1864	.190
1863	.150
1862	.122
1861	.109
1860	.109
1858	.109
1858	.105
1857	.114
1856	.109
1855	.114
1854	.109
1853	.101
1852	.101
1851	.101
1850	.101
1849	.101
1848	.105
1847	.114
1846	.109
1845	.114
1844	.114
1843	.114
1842	.118
1841	.126
1840	.122
1839	.130
1838	.130
1837	.138
1836	.134
1835	.126
1834	.122
1833	.118
1832	.122
1831	.130
1830	.130
1829	.130
1828	.134
1827	.138
1826	.138
1825	.138
1824	.134
1823	.146
1822	.162
1821	.162
1820	.170
1819	.170
1818	.186
1817	.195
1816	.207
1815	.223
1814	.255
1813	.235
1812	.207
1811	.203
1810	.190
1809	.190
1808	.195
1807	.178
1806	.109
1805	.182
1804	.182
1803	.182
1802	.174
1801	.203
1800	.207

Source: Based on the Consumer Price Index as computed by the Bureau of Labor Statistics. 1800–1970: *Historical Statistics of the United States*, series E-135. 1970–1980: *Statistical Abstract of the United States, 1981*, table xx. Refigured to 1980 base and rounded off to the nearest tenth of a cent.

Notes

Finding and Development Costs

Read the table below, then answer the questions on a separate sheet of paper.

Oil Finding and Development Cost* per barrel, 1974-1978

Africa	$1.27
Canada	$2.45
Far East	$0.90
Middle East	$0.12
South American & Mexico, not including Venezuela	$0.34
United States	$4.06
Venezuela	$0.18
Western Europe	$1.48

***Finding cost** is the cost of exploring for oil. For example, if $100 were spent looking for oil in the United States in 1980, and the only oil field discovered contained 10 barrels of oil, it would have cost $10 a barrel to find the oil.

Development costs are the expenditures needed to get a newly discovered field ready to produce oil. Development costs include such costs as the cost of drilling wells to extract oil you know is there, or of laying pipelines around a field to gather the oil extracted.

Finding and development costs are two of the producers' costs for supplying oil.

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1. What years does this chart describe?

2. In what part of the world was it most expensive to find and develop new oil fields?

3. In what part of the world was it least expensive?

4. If the selling price of oil was $1 per barrel, would people have looked for oil in Africa during this period?

5. Suppose the selling price was $1 a barrel but producers expected the price to rise. How would that affect their willingness to search for oil?

6. Suppose the selling price was $1 a barrel. Would people look for oil in the Middle East?

7. If people don't look for oil, what happens to the oil reserves? How do you think that will affect the suppliers' willingness to sell a given amount of oil?

8. In July 1974 the world market price of oil had risen dramatically to around $10.40 a barrel. Oil imported into the U.S. was selling for around $12 a barrel. Under price controls in the United States, the maximum lawful price for oil produced from old wells was $6.85 per barrel. The price of oil from wells that had not been producing oil in 1972 (newly discovered wells) was not controlled, and that oil sold for around $10 a barrel.

If you were an exploration company in 1974, would you look for oil in the U.S. or in another country?

9. List some other costs an oil company might incur between the time the crude oil is extracted and the time gasoline is pumped into your car.

For extra credit

10. Do you think an oil company can calculate its finding costs for oil for the coming year fairly accurately, or are finding costs something that can only be known in hindsight? Explain your answer.

11. You run an oil company. Your finding and development cost has been $3 a barrel. The current price of crude oil is also $3 a barrel. You can borrow money from the bank, long-term, for 10% a year. You must decide at what price for oil it would be sensible for you to drill. What factors will affect your decision?

12. Pretend you are the president of an oil company. You have to choose between spending on exploration or spending on developing a field from which you are already extracting oil. What would you do? Why?

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Answers and background information for the activity sheet **Finding and Development** Costs.

1. 1974 through 1978.

2. The United States, at $4.06 a barrel.

3. The Middle East, at 12¢ a barrel.

4. Probably not. No one can go on spending $1.27 to find something he can only sell for $1. According to the chart, the finding and development cost in Africa during this period was $1.27.

If the potential explorers looked beyond the years covered by the table, other considerations might influence their decision. For example, from 1974 to 1978 geologists might have been obtaining expensive information that would lower future finding costs. And, see the next question.

5. If producers expected the price of crude oil to rise they might be willing to incur finding and development costs that they could not recover at present market prices because they would hope to sell the oil they found at a higher price in the future. It would be an investment, like putting money in a savings account in a bank in order to take out more money in the future. Of course, it would be a much bigger gamble. Question 11 gives students a chance to investigate such a decision.

6. Yes, provided the other costs involved in getting the oil aboard ship did not bring the price over a dollar.

7. If no one looks for oil, no new fields will be discovered. Gradually the oil in existing fields will be extracted, and there will be less oil in reserves. The less oil in their inventories, the smaller the quantity suppliers will be willing to sell at a given price.

Oil being a finite resource, ultimately a similiar process will occur regardless of exploration effort.

8. The difference between the price of oil at the wellhead overseas and in the United States was about 50¢?. If you expected this price differential to continue, you might want to drill abroad, other things being equal.

But other things are not equal. Some of the other considerations that might affect your decision would include:

Political stability abroad. Would the chance of the government taking over your investment be greater abroad than in the U.S.? Would the chance of destruction through war or revolution be greater abroad?

Access to markets. You might feel it would cost less to get oil produced in the U.S. to market. You might feel that the U.S. market was more stable than the market abroad.

9. Other costs an oil company might incur in getting gasoline to consumers include:

transportation

refining

advertising

rental and maintenance of stations,

and so on.

For extra credit

10. Both possibilities are correct. It is certainly true that the actual finding costs can only be known after the money has been spent. The finding costs given in the table, for example, are calculated after the fact and are based on the results of the entire industry. But every oil exploration company must make an **estimate** of its finding costs in order to reach a decision on where to explore and how much money to spend on exploration.

Estimating finding costs in advance is easier in some situations than in others. If you are a small company that drills only one wildcat well, there is a high probability of your finding costs being very different from the industry average, and very hard to estimate accurately in advance. If you are a large company drilling many exploratory wells in many different areas, your finding costs will probably be closer to the industry average and much more predictable. So, to some extent, finding costs for the coming year can be calculated with some degree of accuracy.

11. Some of the factors that affect your decision might be:

What you think the long-range trend of oil prices will be

The geological information you have and the drilling opportunities open to you

How long your money would be tied up in the project and what might happen to the cost of money during that time; that is, what the return on alternative uses of the money would be

12. Perhaps the major factor in your decision will be the element of risk. Both the cost and the return from developing the field would be relatively certain. You can decide how much to spend on exploration, but the return from exploration is uncertain. You might find a new superfield, or you might get nothing. Under these circumstances, the tendency is to invest in developing the field you already have.

SOME OIL FINDING COSTS IN DOLLARS PER BARREL

(For exploration in the United States)	1978	1979
Atlantic Richfield	4.28	13.52
Conoco, Inc.	6.66	7.33
Exxon	11.00	9.95
Standard Oil Indiana	5.80	7.75
Mobil	7.15	9.27
Shell Oil	5.91	5.81
Standard Oil Ohio	32.22	26.68
Sun Company	3.03	9.77
Texaco	4.60	9.55
Weighted average*	8.14	9.92

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*Weighted by barrels found

No Way of Getting Energy Is Free

Why This Lesson

People often describe some forms of energy supply, such as wind power, as "free." Such descriptions show the speaker has not yet grasped the fundamental economics of energy supply. In this lesson, students learn that the **factors of production** are always employed in energy supply. In a later lesson, the recognition that these factors have alternative uses can be used to lead to the understanding that no way of supplying energy is without costs.

Objectives

As a result of this lesson, students will be able to:

Distinguish between labor, capital, and natural resources.

Illustrate the need for all three factors of production in energy supply.

Vocabulary

cost
labor
capital, capital equipment
natural resource

Format of the Lesson

Teacher demonstration of production

Class identification of factors of production

Definition of labor, natural resources, and capital

Completion of worksheet **What Do We Use in Getting Energy?**

Discussion of worksheet

Assignment of worksheet **Using Resources to Get Energy** as homework

On following day, review of homework sheet

Materials Needed

for suggested "production" demonstration

hammer

nails

pieces of wood get two pieces of scrap from the school shop instructor, the same width (say, about 5") and between 5" and 8" long. You will nail these together at a right angle to make a crude bookend.

worksheet **Using Resources to Get Energy,** one per student.

worksheet **Other Uses of Resources,** one per student.

CONDUCTING THE LESSON

Demonstrating Factors of Production

Begin the class with a demonstration in which you make something. Obviously, it should be something simple. Here a "bookend" is described, but it could be a paper airplane or anything else (let us know what you choose so we can pass it on in future editions).

You might tell the class something like this:

"You know, I need a bookend. People are always thinking they need one thing or another, so what do they do? They go out and make it. Or they get somebody else to make it for them.

"To make my bookend, I'll use this wood I got from the shop. Then we'll just hold it together like this—looks like I need some help. Jennifer, would you please hold this board up like this while I nail them together. That's good. Okay, I nail them together and there's my bookend."

Labeling the Factors of Production

"You saw me make something.

"This is a pretty simple-minded project, but it is like any project of any size in the kinds of things that were needed to carry it out. To make the bookend, what was needed?"

The students' responses will fit into one of the following categories. As the categories are identified, write them on the chalkboard. The order in which the factors are discussed makes no difference.

1) Typical student responses: "You had to nail it together." "Work." "Work had to be done."

Things don't get done unless people do them. Economists call this **labor.**

2) Typical student responses: "You needed wood." "You had to have something to make the bookend out of."

"In order to do anything, we have to take things from our environment, things we haven't made. We call these **natural resources.** Even when what we do doesn't result in a product like a bookend, it always involves taking things from the environment. For example, to deliver a message to the principal's office, you would have to take food and air from the environment."

3) Typical student responses: "You used a hammer." "Tools."

"To do most of the things we do, we use things we have made before that make it easier—or even just make it possible—to do what we want to do. Economists call such things **capital.** A hammer is capital. This school building is also capital, and so is the street outside. Anything we make and use in providing more goods or services is capital.

"People sometimes confuse capital with money. Money is not capital, but money can be traded for capital. For example, I can't use a five-dollar bill to build a bookend, but I can go to a hardware store and trade the five-dollar bill for a hammer that I could use.

"Economists have a special name for these three things —labor, natural resources, and capital. They call them **factors of production,** meaning that they are what is needed to produce anything."

Providing for Student Practice in Identifying Capital, Labor, Natural Resources

Pass out the worksheet, **What Do We Use in Getting Energy?**

The chief purpose of this worksheet is to ensure students are familiar with the names of the factors of production.

Do the first three examples orally, by calling on students.

Ask students to complete the worksheet during the remainder of the period. Circulate and check answers.

If time remains, discuss the answers.

Assign the second worksheet, **Using the Factors of Production to Get Energy,** as homework.

What Do We Use in Getting Energy?

Listed below are some ways people can get energy. To obtain this energy, it is necessary to use labor, capital, and natural resources.

Write either "labor," "capital," or "natural resource" in the blank space at the end of each line, to describe what the thing in the second column is. Remember that:

Labor is people's time and effort.

Capital is anything people have made in the past that can be used to make more goods and services. A hammer is capital, and so is a truck, a factory, or a road.

Natural resources are things we take from nature, like ores, water, air, and sunshine.

To do this ...	Requires this ...	What is it?
1. Heat a home with a wood stove	wood	
2. Heat a home with a wood stove	sawing wood into chunks	
3. Heat a home with a wood stove	ax	
4. Heat a home with fuel oil	tanker truck	
5. Heat a home with natural gas	pipeline system	
6. Heat a home with a solar collector	installation by plumber	
7. Move a car using gasoline	drilling rig	
8. Light a home	dam, turbine, and generator	
9. Fly from Chicago to New York	oil refinery workers run refinery	
10. Truck beef to market	crude oil	
11. Make glassware	natural gas	
12. Cook a meal on a gas stove	watching the pot	
13. Pump water with windmill	wind	
14. Running an electric heat pump	coal for the power plant	

Answers and Background Information for the worksheet What Do We Use in Getting Energy?

1. Wood is a **natural resource.** If there were no people, there would still be wood.

2. Sawing the wood into chunks is **labor.**

3. An ax is **capital** equipment. It is a tool someone made.

If students pooh-pooh an ax as capital, here are a few historical examples of the impact of investing in axes. Because they had iron axes (see page 6-1), some of the early European settlers of North America were able to clear forest rapidly enough to establish farms before their supply of imported food ran out. If they had had to rely on the capital used by the Native Americans, (who felled trees using stone axes and fire) they could not have accomplished the job, since it took a Native American an entire day to fell one tree. So in a sense an investment in axes won a continent for the Europeans.

Another example of the importance of the ax as capital is the spread of the Bantu peoples to East Africa. Some historians believe that the migration of the Bantu from the area that is now Nigeria through the Congo forest to East Africa was touched off by the discovery of iron smelting in Nigeria. Iron tools made it possible for the first time for the Bantu to cope with the forest. Without iron axes, agriculture in the dense equatorial forest was too difficult.

4. Tanker trucks are **capital** resources.

5. The pipeline system is a **capital** resource.

6. The plumber's work in installing the system is **labor.**

7. The drilling rig is **capital** equipment. It is a tool people made.

8. The dam, turbine, and generator are **capital** equipment.

9. **Labor.**

10. Crude oil is a **natural resource.**

11. Natural gas is a **natural resource.**

12. **Labor.**

13. The wind is a **natural resource.**

14. **Natural resource.**

Using the Factors of Production to Get Energy

To get energy, it is necessary to use labor, capital, and natural resources.

Labor is human time and effort.

Capital is things people have made in the past that they can now use to make more goods and services, like a hammer or a road.

Natural resources are things we take from nature, like ores, water, air, and sunshine.

Below are some ways people use energy. For each way of getting energy, give an example of labor, capital, and a natural resource used. There are many possible right answers.

1. A family heats their home with a wood stove, using wood the family members cut in their own woodlot.
Labor:
Capital:
Natural Resource:

2. A boy makes toast in an electric toaster using electrical energy from a nuclear power plant.
Labor:
Capital:
Natural Resource:

3. A glassware factory uses natural gas to melt glass, and makes bottles.
Labor:
Capital:
Natural Resource:

4. A man burns gasoline in a car to drive to the supermarket. The gasoline was made from crude oil from an off-shore oil rig.
Labor:
Capital:
Natural Resource:

5. A farmer uses a windmill to pump water for irrigating his crops.
Labor:
Capital:
Natural Resource:

6. Two kids watch TV; the electricity comes from a power plant burning coal that was mined underground hundreds of miles away.
Labor:
Capital:
Natural Resource.

Answers and Background Information for the worksheet **Using the Factors of Production to Get Energy**

Answers given are typical. There are other answers that would be equally correct.

1.
Labor: Felling the trees, cutting the wood, stacking it, stoking the stove, cleaning the chimney, removing ashes. (Labor embodied in capital doesn't count.)
Capital: Ax, chain saw, saw, wood stove, perhaps a wheelbarrow or truck, chimney, stove, shovel, ash pail.
Natural resource: wood.

2.
Labor: Work of plant engineers, work of linemen.
Capital: The nuclear power plant, the transmission and distribution system, the toaster. Going farther back in the nuclear fuel cycle, other capital equipment required would include the equipment at the uranium mine and the milling and enrichment facilities.
Natural resource: uranium.

3.
Labor: Work of the factory workers.
Capital: The factory building itself, the melting pots, the other equipment.
Natural resources: Natural gas, sand, other ingredients in the glass.

4.
Labor: workers on the rig, refinery workers, tank truck driver, service station attendant.
Capital: ships, rig, tank truck.
Natural resources: crude oil.

5.
Labor: maintain windmill.
Capital: pump, tower, windmill blades.
Natural resources: wind. Note that other natural resources were needed to create the capital resources used in obtaining energy from the wind.

6.
Labor: Coal miner, power plant workers, linemen.
Capital: Coal mining equipment, railroad (very probably), power plant, transmission equipment.
Natural resource: coal, air (for combustion), probably water for cooling.

Opportunity Costs of Using Labor, Capital, and Natural Resources

Why This Lesson?

The earlier lesson, **No Way of Getting Energy Is Free,** taught that the factors of production—labor, capital, and natural resources—are used in every way of getting energy. This lesson reviews that understanding and emphasizes its relation to the idea of cost, making the point that, because we give up alternative uses of labor, capital, and natural resources when we use them to get energy, there is a cost to every way of getting energy.

Objectives

This lesson contributes to students' understanding of the following ideas:

All factors of production are needed to obtain energy.

There are other uses for the labor, capital, and natural resources we use to obtain energy.

When we use labor, capital, or natural resources to obtain energy, we give up alternative uses of that resource. This is a cost.

Materials Needed

worksheet **Other Uses for Resources That Could Be Used to Get Energy,** one per student.

Format of the Lesson

Review the factors of production

Do worksheet: identify alternative uses

In discussion of items, show that the cost of using a resource for one purpose is related to the value we place on alternative uses

Summarize: Giving up alternatives is a cost; there are always alternatives, hence there is always a cost

CONDUCTING THE LESSON

Reviewing the Factors of Production

If you have not discussed in class the answers to the two previous worksheets, **What Do We Use to Get Energy?** and **Using Resources to Get Energy,** you can use such a discussion to introduce this lesson. If you have already discussed both worksheets, briefly review by asking students to name the factors of production. Ask a student to name one means of obtaining energy. Ask three other students to give examples of the labor, capital, and natural resources involved in that means of obtaining energy.

Conclude that the factors of production are always used in getting energy.

Other Uses of the Factors of Production

Pass out the worksheet **Other Uses for Resources That Could Be Used to Get Energy.** This sheet may be worked in class. Suggest to the students that the class work the first few items together.

Solicit several examples of alternative uses of Item 1 (land for a windmill), each from a different student. List these on the chalkboard. Establish that there are many reasonable, *technically feasible* alternative uses for the land, as there are for all of the items. There are no "right answers."

Suppose we actually owned the land and had to decide which of these many alternatives to use it for. Do some uses seem more far fetched than others (uses we wouldn't seriously consider if the land was suitable for a windmill or some of the other uses named) and some uses quite attractive? Why? Of course, the worksheet doesn't provide enough information about the land for us actually to decide what we would use the land for.

An Example of Opportunity Cost

For example, suppose I told you the land this windmill stands on is at the very top of the *only* mountain in a populous county. It is by far the best site for an antenna for television broadcasting. Unfortunately, the turning windmill blades interfere with broadcasting, so you can't have both. Do you think people would erect a TV antenna or a windmill on it?

Do you think that its being the only TV antenna site increases the cost of putting a windmill on it? What if there were three or four equally good antenna sites, how would that affect the cost of building a windmill on this land?

What if no one lived within hundreds of miles of the site?

Our decision to use a resource depends not just on what we're getting, such as the electricity from the windmill, but also on what we're giving up, in this case, the possibility of using the land as an antenna site. The greater the value to us of the next-best thing we could do with labor, capital, or a natural resource, the costlier it is to use it for whatever we think the best use is.

For example, suppose you spend an hour on homework each night. You will feel you're giving up more on the night you have to miss your favorite TV show than you do on the night nothing you like is on. The loss of the chance to watch a TV program is a cost to you, and the **cost** is higher when it's a program you really want to see.

Completing the Worksheet

You may choose to continue with the items orally or, when the students understand what is wanted of them, they may complete the worksheet silently. Then discuss the items. During the discussion, try to help the students identify a second-best use of each item. Relate the value of the foregone alternative use to the cost of using the item to obtain energy.

Answers to the Worksheet

These are only examples. Obviously, there are many possible answers.

1. Grow crops. Build a house. Mine it. Build a swamp and raise mosquitoes. Build an antenna.

2. Synthesize chemicals from it. Leave it in the ground as an aquifer.

3. Plant something. Cultivate something. Read the farm news. Have fun with his or her family.

4. Similar to answers to Item 3.

5. Make into lubricating oil. Make into plastics.

6. Make atomic or hydrogen bombs. Color glass yellow. (Depleted uranium—U-238—is used as ballast; for example in the tails of commercial jetliners.)

7. Grow something else on the same location. Put up photovoltaic cells. Put up solar collectors.

8. Drill for water. (Of course, there are differences between oil rigs and water well rigs, but in a pinch....)

9. Make a pipeline for crude oil, refined petroleum products, coal slurry, or water. Melt the pipe and use the iron for something else.

10. Build roads. Build buildings. Build hydroelectric dams.

11. Surface-mine copper, perhaps. Excavate buildings, perhaps. "Perhaps" because highly specialized machines like these are built for a very particular purpose, or even a particular site. We have to look one step beyond this piece of capital equipment, and ask what other machines might have been built with the resources that went into this piece of capital equipment.

Other Uses for Resources That Could Be Used to Get Energy

Worksheet

Here are some resources you or other students have named on the worksheet called "Using the Factors of Production to Get Energy." For each resource, name some other use it could be put to.

Resource	Example of use to get energy	Example of use for another purpose
1. land	has a windmill on it	
2. coal	burn it	
3. farmer's time	oiling windmill	
4. family's labor	fell tree, split wood	
5. crude oil	make into gasoline for cars	
6. uranium	make into reactor fuel	
7. sunlight	grow trees for fuelwood	
8. drilling rig	drill for oil or gas	
9. iron pipe	make a pipeline for natural gas	
10. concrete	make containment building of nuclear power plant	
11. power shovel	use to surface-mine coal	
12. natural gas	to power compressors that push gas through the pipelines	
13. ship	carry crude oil from Africa to the United States	
14. wind	drive a windmill	

12. Make fertilizer. Heat homes. In some parts of the world, gas produced as a part of crude oil production is "flared off," simply burned at the well. What does this suggest about alternative uses for the gas at those well-heads?

13. Carry other goods. But, same problem as in Item 11.

14. By using the wind to drive this windmill, we forego the chance to have a wind generator producing power at another site immediately downwind of this one. This is a very small cost, but point out that there are other uses for the capital (steel, copper wire, etc., depending on the construction of the windmill) and the labor used to obtain this energy. So wind itself is cheap *because the alternative uses are few and little-valued,* i.e., we give up very little in using it to drive a windmill, but wind power is not free.

Concluding Discussion

Summarize the discussion by concluding that there is always another use for any of the factors of production that we employ to get energy.

The Role of Capital Resources: Productivity

Objectives

This lesson contributes to students' understanding of the following concepts:

The use of capital goods often makes possible methods of production that result in a lower cost of production.

To accumulate capital resources, consumption must be deferred.

Format of the Lesson

(This lesson is based on a simulation)

Explain rules of the activity

Conduct activity

- introduce scissors
- introduce punch

Debriefing

In following class period, compare activity results with historical date

Materials Needed

"musket wad" raw materials 60 sheets of paper dittoed with a pattern of two concentric circles, the inner circle ¼" in diameter, the outer circle ½" in diameter. Make from the master supplied.

plain paper about 30 sheets.

scissors one pair per student.

pliers-type paper punch about one for every three students.

tally sheet make one copy from the master supplied or, if you usually use an overhead projector, make an overhead transparency.

overhead transparencies of the historical examples you wish to use in the post-activity discussion.

rewards raisins, peanuts, sunflower seeds, or some other edible item with a low unit cost.

TYPICAL COSTS OF VARIOUS REWARDS

Reward	Cost of 1 lb.	Quantity in 1 lb.	Unit cost	Suggested exchange rate: wads per reward
Raisins	$1.60	1,000	.16¢	5 wads for a raisin?
Roasted Virginia peanuts in the shell	$1.40	400	.035¢ per kernel	5 wads for a nut?
Salted, roasted sunflower seeds (in the shell)	$1.50	3,200	.047¢	1 wad for a seed?

The Game

In this activity, students tear out small circles of paper ("musket wads"). These can then be traded for edible rewards. After production has begun, students are given the opportunity to trade wads for tools (scissors, and then paper punches) instead of the edible reward. Students who invest in the tools are able to greatly increase their production of wads, and thus the number of rewards they get by the end of the activity.

Alternate Versions

Several versions of the activity are possible. Choose the one that offers the best trade-off in learning, expense, and convenience in your classroom.

Version A: During the game you circulate around the room, offering to buy musket wads the students have made for a fixed price, say 10 wads for a raisin. Students may trade the wads for an edible reward *at any time* during the game. The object is to see how many rewards one can accumulate before the end of the game. If you have a rule against eating in class, the class must be told the rule is waived during this activity.

The disadvantages of Version A are:

Students get more rewards in this version, and the rewards cost money.

Students must be allowed to trade saved rewards for the capital goods, in addition to the wads. The traded-in rewards must be discarded in the interest of public health. This wastes food.

Version B: At the *end* of the game, students may trade musket wads in their possession for rewards, at an exchange rate specified at the start of play, such as 10 musket wads for a sunflower seed.

The advantage over A is that B is neater and more sanitary, and no rewards are wasted.

The disadvantage is that under Version A, some students will collect their rewards during play and eat them. Thus they forego the opportunity to accumulate capital (scissors or a punch). Eating the rewards during class provides a living example for post-activity discussion of the need to defer present consumption to increase future productivity.

Version C: A prize is offered at the end of play to the student who has the most wads in his or her possession.

This greatly reduces the expense of the rewards.

The disadvantages are all those for version B, and, in addition, students who perceive themselves to be hopelessly behind are liable to tune out of the activity.

Before the Lesson

Before doing the activity:
1. Decide which version you will do.
2. Practice tearing out a wad or two.
3. Enter your students' names on the tally sheet. (A student can do this for you.)
4. Make sure you have all the materials.

Introducing the Activity

The explanation used to introduce the activity can run something like this:

"Today, everybody is going to get a chance to be an old-time manufacturer.

"Pretend it's hundreds of years ago. People are using muskets to put the squirrel in their stew, the wild turkey on the table. Muskets are like rifles except that you don't load them with a nice neat bullet. To load a musket, you dump some gunpowder down the barrel. Then you take a musketball, which looks like a lead marble, wrap it in a piece of cloth, stick it in the muzzle, and push it down the barrel with a rod.

"Now, because of budget cuts, our musketballs are only the size of a BB. And instead of cloth for our musket wad, we have to use paper. So for our musket wads we need some little circles of paper. Here they are." [Show the sheets of paper with the printed circles.]

"The ideal musket wad is a paper circle ¼" in diameter, but any wad is acceptable if it has *all* of the inner circle and *none* of the outer circle. To make these little circles you take the raw material and tear out circles, like this." [Demonstrate tearing out a musket wad by hand.]

"These musket wads are valuable items. There is a big demand for them from BB musket owners."

[Here you must use a wording to match the version you have chosen. Here's a suitable wording for version A.] "I will buy all the musket wads you can make, at the rate of ten musket wads for one raisin [or sunflower seeds, or peanuts, or whatever you wish]. Any time you wish, you can come up and trade musket wads for raisins."

[For version B] " At the end of the game, I will trade you one raisin for every ten musket wads you've made."

[For version C] "At the end of the game, the person who has the most musket wads will get a prize." [Be careful not to say "the person who has made the most," because wads traded for scissors and punches don't count. It might be possible for the person who had made the most wads not to have the most at the end, due to purchases of scissors and punches.]

Set a definite time for the game to end and write it on the chalkboard. (*Very* important!) Try to allow about 15 minutes for play and 15 for discussion afterwards.

Warn the students that you will have some special announcements to make during the game. When you say "freeze," everyone is to stop making wads immediately and listen to the announcement. They are not to begin again until you say "begin."

Give each student two musket wad forms and indicate where more forms and plain paper can be obtained.

Specify that only materials you have supplied for the activity can be used. No other raw materials or tools are allowed.

HAVE YOU COVERED ALL THESE TOPICS?

A salable wad = all inner circle, no outer circle

Exchange rate from wads to rewards

wads per raisin, sunflower, or peanut

wads for a pair of scissors

wads for a punch

Time you will stop

No raw materials or tools not teacher-supplied

Everyone "freeze" for special announcements

If so, tell students they may start.

The First Innovation

Observe the tearing-out of musket wads. Give some quality control help to those whose wads are not meeting the salability criteria of *all* the inner circle, *none* of the outer. Exchange wads for rewards for a few fast, hungry students. After a few minutes, when several students have accumulated 20 wads, say:

"Freeze! Everybody freeze!"

Announce that a student can get one pair of scissors for the price of 20 musket wads. If you are doing Version C, be sure to make it clear that *the 20 musket wads traded for the scissors don't count toward the prize.* Allow the activity to proceed until several pairs of scissors have been "purchased." On your tally sheet, place a checkmark after the name of each student who buys a pair of scissors.

The Second Innovation

"Freeze. Everybody freeze!"

Announce a "new invention": the automatic musket wad maker, and hold up a pliers-type paper punch. Any student can obtain the use of this elaborate piece of modern machinery by trading in 50 musket wads.

Explain that all the wads made by the punch are perfect (unless they are not a full circle) and the pre-printed paper should not be used. Plain paper can be used instead.

Do not accept trade-ins of scissors for punches. As a prestigious manufacturer of industrial machinery you are not in the market for obsolescent equipment.

On your tally sheet, place a checkmark in the appropriate column whenever a student buys a punch.

Continue to the previously announced stopping time. Have students count the number of wads prepared, and exchange them for rewards in accordance with the version you are using.

Student Variations

In the course of the activity, students may introduce variations of their own. If they do, you are fortunate in having wide-awake students. All the following actions, for example, are permitted under the rules given above:

Two students with scissors join forces. One cuts the paper into strips, making cuts parallel to the long side of the paper that just miss the inner circles, and the other cuts the inner circles from the strips. This technique rivals the punch in productivity. (After the activity, discuss the effect specialization of labor may have on productivity.)

A student who buys a punch sells his scissors to a scissors-less classmate for less than the teacher is asking. (After the activity, discuss what factors determined the price of the scissors.)

A student punches several thicknesses of paper at a time.

A student who is able to purchase several punches may hire another student to work a punch for her, promising him a share in the proceeds. (After the activity, discuss capital and employment.)

After the Activity

Complete the tally sheet, even if the activity has run over time. You need these data for the discussion. Of course, it is much better to have a discussion immediately after the activity than the following day.

Questions for Discussion

If you have completed the tally sheet as an overhead transparency, project it. Then discuss the following sequence of questions.

1. Who had the most rewards by the end of the game?

2. Did people with scissors do better than those without? How did those with punches compare to those with only scissors?

3. What did the people who "bought" scissors and punches give up? Can you eat scissors and punches? Why did they trade?

Help the class see that acquiring tools—capital goods —made students more productive. But they had to choose between tools and eats; getting capital involves giving up some *present* consumption in the hope of greater future consumption.

4. Could the students who traded for scissors and punches be certain they would end up with more rewards?

Is This the Way the World Is?

What happens in an activity like this is not necessarily an accurate picture of what happens in the world at large. So let's look at some examples of times when doing something by hand was being replaced by doing it with machine. To do that, let's look back almost a hundred years.

Project the **Weaving** transparency. Point out that this shows what was used to make one square yard of cotton sheeting, cloth like that used to make bedsheets. The items at the top show what was needed to make this cloth by hand in a household in 1860. The items at the bottom show what was used to make this cloth in a factory in 1897.

One factor of production is not mentioned. What is it? (ANS: Natural resources.) What natural resource would be used? (ANS: Cotton.) Natural resources are not mentioned because roughly the same resources were required. Later we will come back to see what the difference was.

Use questioning to get the students to interpret the items on the transparency. Which method of production used more capital? Which used more workers? Which used more labor? About how many times more labor was required to make a yard of cloth by hand (ANS: About 106 times more labor. 11.21 hours x 60 minutes in a hour = 672.6 minutes; 672.6 divided by 6.33 = 106.26.) Point out that capital has been **substituted** for labor. Another factor of production has also been substituted for labor.

Looking at the list of capital equipment used in the factory, can you discover a natural resource the factory needed that the household didn't. (ANS: Mule food.) True, anything else. (ANS: Fuel for the steam engine. In 1897, this would probably be coal.) So the natural resource coal was also being substituted for labor.

Project the transparency on **Mining.** Call upon students to interpret the information on the transparency.

Elicit from the students the conclusion that capital can be substituted for labor, as can natural resources that provide energy.

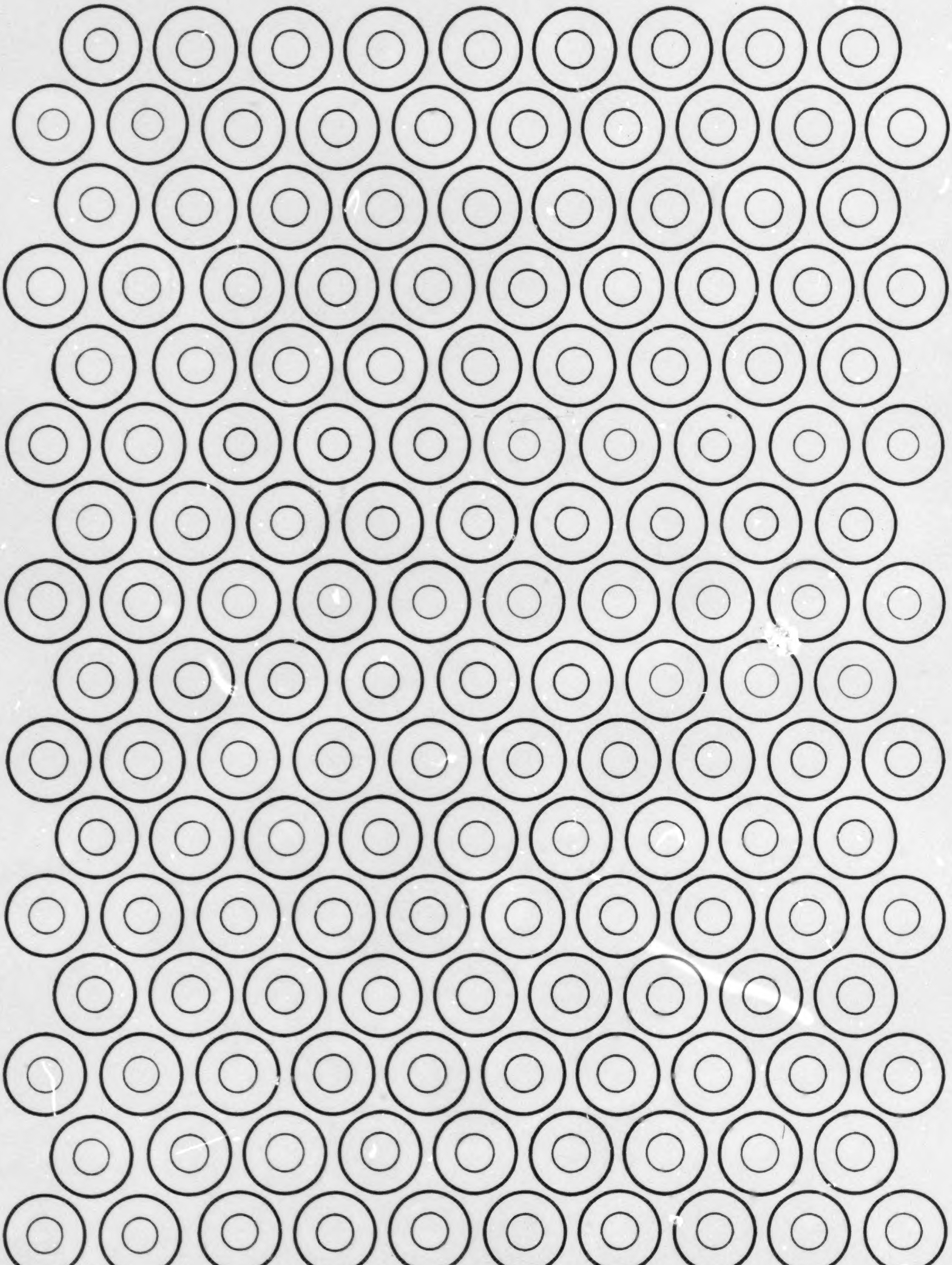
A Related Lesson

Unit Six, Energy in American History, has a sequence of lessons (page 6-51) dealing with a related topic. If those lesson plans have not been used with your students, you may wish to examine them.

Projects for Independent Investigation

1. Using current periodicals as a source of information, make an oral report comparing the use of industrial robots in the United States and Japan. Try to explain any differences you find.

MASTER



Substituting Capital for Labor in Weaving

Factors of production employed in making, in the United States, one yard of 36-inch wide unbleached cotton sheeting

Year: 1860

Capital: tub and sticks, cards, spinning wheel, loom, shears

Labor: housewives (3 of them, working between other household chores)

time: 11.21 hours of work

Year: 1897

Capital: breaker machine, finisher machine, card-grinding machine, carding machine, drawing frame, slubbing frame, speeder frame, spinning frame, warping machine, slasher machine, loom, steam engine

Labor: factory hands (282 different people, plus some mules)

time: 6.33 minutes of work

Source: **Thirteenth Annual Report of the Commissioner of Labor, 1898. Hand and Machine Labor.** U.S. Gov't Printing Office, Washington, DC 1899. Page 40 & 41, Volume I; pp 970 & 971, vol. II.

Substituting Capital for Labor in Mining

To mine 100 tons of coal

Year: 1895

Capital (to remove coal from seam): pick and shovel

Labor: 387.5 man-hours

Year: 1897

Capital (to remove coal from seam): electrical mining machine

Labor: 191 man-hours

Source: **Thirteenth Annual Report of the Commissioner of Labor. 1898. Hand and Machine Labor.** U.S. Gov't Printing Office, Washington, DC 1899. Pages 76 & 77, vol. I; pp 1578 - 1579, vol II.

Tally Sheet for Musket Wad Activity

Student Name	Scissors?	Punch?	Rewards in possession at end of game + rewards eaten

Notes

Internal and External Costs

Why This Lesson?

The processes of supplying energy and using it have always created large costs not borne by the individual who used the energy. Such costs are called **external** costs. A typical external cost is the damage caused by energy-related pollution. Almost every way of supplying or using energy creates pollution. Though modern Americans are most familiar with pollution caused by using gasoline, coal and other fossil fuels, around the turn of the century the enormous amount of horse manure in the streets was a major health problem in our cities.

In recent years, laws have been passed to try to **internalize** some energy-related external costs, for example by requiring pollution control or increased mine safety. An external cost is internalized when the buyers of a good or service pay that cost.

To understand what has happened to energy prices in the last decade and anticipate future effects, students need an awareness of the existence of external costs as well as some understanding of how internalizing external costs increases suppliers' costs and thus the purchase price of energy. For example, some economists feel that the quadrupling of coal prices has been due in large part to regulations that internalized various external costs related to pollution and the health and safety of workers.

Objectives

As a result of this sequence of lessons, students will be able to:

Distinguish between internal and external costs.

Give examples of external costs incurred in energy supply.

Recognize pollution as an external cost.

Give examples of ways of internalizing some external costs incurred in supplying energy.

Describe the effect that internalizing external costs has on the supply curve.

Materials Needed

To determine how many copies of the readings will be needed, please see the discussion below on alternate ways of conducting the lesson.

reading **The New Take-Out Restaurant and the Park**

reading **The New School**

reading **The Lettuce Crop**

reading **Lumbermen and Fishermen**

reading **Coal Train**

reading **Windmill**

reading **Wood Smoke**

reading **Reactor**

activity sheet **External Costs of Energy Supply,** one per student.

Format of the Lesson

Class discussion reviewing suppliers' costs and how they affect price

Teacher definition of external costs

Group discussions of readings

Groups report on readings

Class discussion of reports from groups

Homework assignment

Background Information: Why the Term "External Costs"?

The type of cost dealt with in this lesson has sometimes been called "unpaid costs" or "social costs." We have not used the term "unpaid costs," because **all** costs are ultimately paid. We have not used the term "social costs," because it conveys to students the mistaken impression that these costs are somehow shared out among the members of society and "nobody pays." In fact, all such costs are ultimately borne by individuals. In this program, we have chosen to describe these costs by the term "external costs." This has the happy advantage of being easily understood as external to the supplier, and also suggests external to the market (externalities).

CONDUCTING THE LESSON

Reviewing Suppliers' Cost

Recall with the class examples of suppliers' costs they studied earlier, in Section 2.

Review how suppliers' costs affect the supply schedule (or supply curve). When suppliers' costs increase, other things being equal, at any given price they will be willing to supply a smaller quantity than they would have been willing to supply before. (The supply curve shifts to the left.) Thus, through market clearing by supply and demand, the market price increases.

(**Note:** In reviewing this model, keep in mind it is a model, and energy prices are strongly affected by non-market forces. For example, laws regulate the prices charged by utilities. In many cases, these laws allow the utility to pass certain cost increases (such as increases in the cost of fuel) directly on to buyers. Gas utilities are often permitted to pass on gas price increases. The demand curve then determines what quantity will be sold at the new price.)

Tell the class that they have been considering only one kind of costs incurred in an economic activity: the costs paid by the supplier. But many activities also create a different kind of cost.

Defining External Costs

Give an example to illustrate what an external cost is. You might use something like this:

"I'm going to be someone who lives in the country and you are my neighbors. I've decided to open an egg ranch, which is perfectly legal—the area is zoned for chicken farming. There are lots of costs involved in running an egg ranch. For example, I'm going to have to buy chicken feed. Will I have to pay for it?" (ANS: Yes.)

"When I sell the eggs, will I have to get the cost of the chicken feed back from my customers?" (ANS: Yes.)

"Now, as it happens there is a problem with my egg ranch. It smells awful. It smells so bad your heads reel. Your eyes water. Have you incurred a cost as the result of my egg ranching?" (ANS: Yes. If students don't believe there is a cost, try pointing out that a) other things being equal, if they wanted to sell their land, they would get less for it than they would have gotten before you opened your egg ranch, b) people not only pay for services and medicines to avoid or cure dizziness and watering eyes, they pay for perfume. The egg ranch activities are depriving the neighbors of something people value.)

"In fact it smells so bad that to continue living in your homes, you have to seal all the windows and go out and buy air conditioners.

"Will I have to pay for your air conditioners?" (ANS: No.)

"Will I pass the cost of your air conditioners on to my customers?" (ANS: No, how?)

"Will the people who buy the eggs reimburse you for the suffering you went through so that the eggs they bought could be laid?" (ANS: No.)

"Your suffering, your inconvenience, the cost of the remedies you bought, are **external** costs of my business. They are costs created by my activity, but they're costs I don't pay. Because I don't pay them, I don't take them into account when I decide how much I'm willing to trade an egg for. The egg-eaters don't care how much you suffer either, because it's no skin off their noses, as the saying goes.

"Chicken feed is an **internal** cost. I pay it. The higher the price of chicken feed goes, the more I'm going to have to get for my eggs in order to stay in business. So indirectly the egg-eaters **do** care about the price of chicken feed, because they want to buy eggs as cheaply as possible.

"Many external costs have to do with activities that release something into the environment, but not all. For example, suppose there is a fatal disease, called "egg pox." Every worker I hire sooner or later gets egg pox and kicks the bucket. That is a big cost to him and his family. But when he dies, I just go out and hire another worker, so it is not a big cost to me (except for having to teach the new worker the job).

"Of course, egg ranches are really not like this. One of the reasons they aren't is that, as external costs are recognized as being big enough to matter, we try to do something about them. Counties pass zoning laws saying you can't have egg ranches in residential neighborhoods. Another approach is to try to make me, the egg rancher, pay these costs. For example, a law could make me keep a safe work place, so workers wouldn't get egg pox, or get crushed by the yolk separator. A law could also require me to keep the place clean so it wouldn't smell. Doing these things would cost me money, but I'll pass those costs on to the egg-eaters. Not only that, but the law would require all my competitors to do the same things, so they won't be able to sell eggs cheaper than I could if I were the only one who kept a clean, safe, egg ranch.

"Now that you know what an external cost is, I'd like you to try to spot them in some real-life situations."

Practice in Identifying External Costs

At the end of this lesson plan you will find masters for eight readings, each describing a situation in which there are one or more external costs. Some of the situations directly involve energy use or supply; some do not. The mixture is intended to help students avoid the misconception that external costs are incurred **only** in energy-related activities.

One way of using the readings is to choose one or two to be read and discussed by the whole class. Another way to use them is to divide the class into groups, have each group analyze one situation, and then conduct a class discussion of the groups' conclusions and the implications. We think the latter method is better because it provides more opportunity for oral expression by individual students, and it exposes the class as a whole to a greater variety of examples. What follows describes the "groups" approach.

Divide the class into groups of four or five. Be sure there is at least one good reader in each group.

Ask students to discuss the questions. Tell them you will be calling on one member of the group to describe the situation to the class, and another to describe the external costs involved.

Have the class break up into groups to read and discuss the passages.

Alternatively, you may wish to give the groups overnight to study their readings. In that case, you may also wish to request written answers to the questions on the sheets.

Discussing the Readings

Call the whole class to order.

Group by group, call on one student in a group to describe the situation described in the reading.

Call on a second student in the same group to describe the external costs involved.

Some of the readings raise special points. There is no need to try to introduce all of these into the discussion.

The Take-Out Restaurant and the Park
How does the "good citizenship" attitude of the restaurant affect the external costs? Affect the restaurant's internal costs? Assuming for the sake of argument that the restaurant's only goal is to minimize its costs (while maximizing revenues), is the restaurant's anti-litter action warranted?

The New School
Note that external costs can be created by activities of the public sector as well as of the private sector.

The Lettuce Crop
Regarding the increase in the value of the land: just because there is a net benefit (assuming there is) does not mean no costs exist.

Lumbermen and Fishermen
From what is said in the reading, what role does technology play in this problem?

Coal Train
The distribution of costs and benefits from an activity may differ by geographic area. In some states, there is great local opposition to certain energy projects because some local residents believe most of the costs of such projects are being borne locally, while most of the benefits are obtained elsewhere. Try listing on the chalkboard costs and benefits for the rural area where the coal is mined and for the city where the electricity is consumed. Similar problems arise from the siting of power plants hundreds of miles from the populations they serve: for example, at mine mouths.

Severance taxes are one way local residents seek to limit such projects and increase benefits to themselves (while increasing costs to the consumers of the electricity). (What other sorts of actions might increase local benefits?)

On the other hand, a good case can be made that the benefits elsewhere are greater than local costs. If we assume this is so, and the development of, say, the coal mine is in the national interest, how will we balance local and national interests? How is this done, politically?

Western coal may be the primary source of the electricity consumed in your town. If so, does this affect students' attitudes toward this situation?

Windmill
Note that the primary benefit is not to local residents (the electricity delivered), but to the people who will obtain electricity in the future at less cost due to improvements in windmills to be built in the future. How is this similar to the situation in "Coal Train"? To medical research?

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Wood Smoke

Suppose there were a technical fix to this problem (as in fact there is—catalytic converters for wood stoves are already on the market), and it involved an added capital expense to wood-burners. By what means could it be implemented? Compare to car exhaust systems. Are there other ways of providing incentives?

Reactor

Are there external costs to TV shows depicting violent criminal acts? What might be an internal cost of removing violence from such a show?

Summarizing the Discussion: Who Pays External Costs?

We know we can divide costs into two kinds.

Internal costs are paid by the business, government agency, or whoever is carrying on the economic activity, and passed on to the buyer. So we know if you buy the benefits, you pay the costs.

External costs aren't paid by the business. So who pays external costs?

Usually, the people who pay the external costs are also receiving some benefits. For example, everyone in a city benefits to some extent or other from motor vehicle transportation. That's how city people get their food and clothing even if they never set foot in a car or bus themselves. Everyone in the city also has to pay some of the external costs, by breathing polluted air, for example. But some people pay more of the external costs of motor vehicle transportation than others. For example, babies living near freeways used to have higher levels of lead in their blood (from auto exhaust), than babies in other parts of the city. But these babies with low-level lead poisoning didn't use transportation more than other babies; probably less (housing tends to be less expensive nearer the freeway; lower income families use less transportation). (How was the external cost of lead poisoning from gasoline internalized?)

If each individual was paying the costs in proportion to the benefits received, then external costs would be just like internal costs. But that is rarely the case. Often, we can define groups with distinctly different cost-benefit ratios.

These groups may be separated by income levels, or separated geographically, as in the "Coal Train" reading. They may be separated in time, as in the "Windmill" reading. For example, we get the benefits of the electricity generated by using nuclear power, and pay some of the costs. Some of the external costs created (effects of released radioactive materials) will be paid by people in future generations, and they will also get some benefits as the result of what we did with the electricity.

What are the problems with external costs? One is that we may not think they are fair. Another is that there is no economic incentive for the person creating an external cost to minimize it, and the cost to other people may be far greater than what it would cost him to eliminate it.

We are going to look at some external costs of energy supply. We will look at them from an economist's point of view. But it is important to remember that economics can make a prediction of what will happen if you do this or that, but it doesn't tell you what to do. That depends on things like what you think is fair, and which of the cost-benefit groups you happen to belong to. For that reason, external costs are as much a political problem as an economic one.

Which of the situations described in the readings are related to energy supply or consumption?

Can we name some kinds of external costs that energy use and supply might often create?

Homework

Assign the activity sheet on page 7-63, **External Cost of Energy Supplied,** as homework.

Answers to the activity sheet, **External Costs of Energy Supply**

1. External. Cost of cleaning the buildings. Perhaps the loss of prestige due to the badly maintained appearance of the building is also a cost.

2. Internal. Cost of drilling: crews, rental of rigs, etc.

3. External. Value of fish no longer harvested. Recreational value of fishing.

4. External. Impaired health, shortened life span.

5. Internal. The company passes the cost of the insurance premium on to customers.

6. This answer depends on whether you feel a value can be put on loss of life. In any event, you would need to know whether the company paid compensation to the families of the dead workers. The item does not provide enough information to make a judgment.

7. External. Cost of loss of productivity of farmland.

8. Internal. The purchase price of the set, the cost of installation.

9. Internal. The woodcutters are their own customers, in effect, and presumably they pay all costs. (But—if their medical costs are paid by insurance, non-woodcutters are paying some of the out-of-pocket medical costs the woodcutters incur in getting their energy.)

10. Internal. The cost of the lost ability to refine oil. (An opportunity cost!)

The New Take-Out Restaurant and the Park

A new take-out restaurant recently opened on the edge of the city park. It is one of a national chain. People from the nearby office buildings now buy their lunches at the restaurant and eat them in the park.

"This is great," says Jane Willaday, a secretary. "I love being able to spend my lunch hour sitting here on the grass instead of in some stuffy restaurant. It's cheaper, too."

However, the park has become noticeably more littered. Most of the litter is food wrappings from the restaurant. People who have been using the park for years have started to complain.

"I take a walk through here every evening," says Barney Oldfield. "I come to enjoy the little bit of greenery that's left in this town. Seeing all this trash spoils my enjoyment. If I wanted to see trash, I'd stay on the city streets."

Park superintendent Lucille Sepulveda says, "We're doing all we can. We had a full schedule already. Now we're spending two hours a day on cleanup, instead of the six hours a week we used to spend. Other chores are being neglected. The hedges haven't been trimmed in two months. We're late planting the tulip bulbs because of all this cleaning up; if we don't get the bulbs in this week, we won't have the spring flower show this park is famous for. Anyway, we won't have any new varieties, because I had to spend the new bulb money for more trash cans. If we're to do any more, we'll have to hire another worker, and I don't think the City Council will give me the money for that."

The manager of the fast-food restaurant says, "We do everything we can to prevent littering. We provide trash cans all around the restaurant. We put up signs asking people not to litter. We print "don't litter" messages on the wrappers and bags we serve our food in. We are just as aware of the problem as anyone else, but what more can I do?"

Answer the following questions on a separate sheet of paper:

1. What new cost did the opening of the restaurant create?

2. What benefits have people obtained from the opening of the restaurant?

3. Who pays the wages of the park attendants?

4. Who pays for the office workers' lunches?

5. What do you think should be done in this situation, if anything?

The New School

A new elementary school has just been built in Mr. Burks' neighborhood. It has a big playground behind it, next to Mr. Burks' house.

"I've lived here forty years," Mr. Burks says, "and when I retired, I'd hoped to live out my days here. But I just can't stand the noise these kids make. They're yelling from nine o'clock in the morning 'til three in the afternoon. I don't mind a few kids. In fact, I like having kids in the neighborhood, but I can't take the noise from a hundred of them at a time.

"I'm having an eight-foot cinder-block wall put up between my house and the school, and I'm having new windows put in that have three sheets of glass in them. The contractor says that'll stop a lot of the noise; he's charging me several thousand dollars to do it. I really can't afford it, living on a pension, but I hate the thought of moving. I hope the new wall and windows work. If they don't, I'll just have to move."

Mr. Andrews, the school principal says, "I sympathize with Mr. Burks, but there's not much the school can do. The students can't be expected not to make any noise during recess and sports. The school had to be built somewhere; I'm sorry it happened to be next door to a resident who is so sensitive to noise."

Answer the following questions on a separate sheet of paper:

1. Who benefits from the school being open?

2. What costs did Mr. Burks pay?

3. Suppose Mr. Burks did not have the money to spend on making changes like building a wall or replacing his windows. Would there still have been a cost to Mr. Burks?

4. Who pays for the school?

5. What do you think should be done in this situation, if anything?

The Lettuce Crop

Once, Pleasant Valley was one of the biggest lettuce- producing areas in the nation. This week its last lettuce crop is being harvested.

Gene Cary, the farmer who grew the crop, explains: "This used to be the ideal place for growing lettuce. The soil was good, we've got water, and plenty of sunlight.

"But about ten years ago we started to notice spots on the lettuce leaves. They didn't look so good in the supermarket, and buyers wouldn't give us top price for our lettuce. The next year it seemed the heads were getting smaller and the plants didn't look so healthy. This was all real gradual. It just kinda crept up on us.

"Finally, a county agricultural agent pinned it down. It's smog, and there's nothing I can do about it. I'm the last one to quit, but next year it's carrots for me. Carrots don't pay as well as a good crop of lettuce does, but I don't get a good crop of lettuce anymore."

Bill Swarthmore, an agricultural scientist at a nearby university, comments, "Pleasant Valley's problem is that they're directly downwind from Big City. The gasoline that's burned in the cars in the city creates smog, and the smog drifts down here. Leafy crops like lettuce are very sensitive to air pollution. The growth of automobile traffic in Big City has just wiped out lettuce farming there."

Eileen Carlisle, the mayor of Big City, comments, "I sympathize with the problems of the farmers of Pleasant Valley. However, I'd also like to point out that, on balance, the growth of Big City has been a blessing for them. Even though their land is no longer suitable for growing lettuce, its value has increased tenfold in the the last ten years, just because it's within commuting distance of the city. It's much more valuable now for homes than it ever was for lettuce. Thanks to cars, these farmers have made a fortune. As the saying goes, they're crying all the way to the bank.

"As for air pollution, we're doing all we can to control it."

Answer the following questions on a separate sheet of paper.

1. Who benefits from the lettuce growing?

2. Who loses when the lettuce can no longer be grown?

3. Who benefits from the activity that makes the smog? Do these individuals pay the cost of the loss in value of the lettuce crop?

4. What do you think should be done in this situation, if anything?

Lumbermen and Fishermen

A meeting is being held in a city in a northwestern state to discuss a problem that many local people feel very strongly about. Fishermen are complaining that debris from lumbering is clogging the small forest streams. Because salmon can no longer spawn in these streams, there are fewer salmon to catch than there used to be. Other fish, like trout, which also used to live in these streams, can no longer do so.

Sven Martinson, owner of a local lumber mill, says: "Today, we have a use for every scrap of the tree that we can get to the mill. It's true, there's debris left on the site. Eventually, it'll all rot and return to the soil, as it has for tens of thousands of years. And it's true, some of it washes into the streams. But we can't clean up all that debris. It would be all handwork, tremendously expensive. To do that would increase the cost of lumber enormously. Lots of people can't afford houses now. What do you want, to eat fish or to have a roof over your head?"

Michael Darley, from the staff of the state fish and wildlife bureau, says, "Cleaning up the streams **is** costly, but it's not that costly. If you change the lumbering technique a little, you can prevent a lot of the debris. It's the areas near the streams that are most important."

Jill Brayman, president of the lumberperson's association, says, "What Mike calls 'changing the lumbering technique a little' sounds like big changes to me. For example, his plan requires that we never harvest steep hillsides next to streams. That's a lot of timber that's going to go to waste."

"You know," says Olaf Jorgenson, captain of a fishing boat, "I'm not just talking about spoiling the fun of a few fly fishermen. I'm talking about a big industry—fishermen, canners, the whole thing. If we don't stop the destruction of streams, in a few years there'll be no more salmon—in my net or on your dining room table."

Answer the following questions on a separate sheet of paper.

1. What costs do the fishermen incur as a result of lumbering?

2. Who benefits from lumbering?

3. Do people who buy lumber pay for the loss of fish?

4. What do you think should be done in this situation, if anything?

Coal Train

Rural City is a small town in a Rocky Mountain state. The railroad track runs through the middle of town, dividing it in half.

Recently, large coal mines have been opened 150 miles north of the town. The railroad carries coal from the mines to electric power plants in other states, and also to seaports for shipment to other countries.

Mike Morley, the town's mayor, summarizes the views of many residents when he says: "This used to be a quiet little town. Well, it's still little, but it isn't quiet anymore. Instead of maybe a train a day. now we have a train every hour, and they **are** noisy."

Mr. Crosby, who owns an ice cream parlor on west Main Street, says: "I know I've lost business because of these trains. People come to town from the farms out east, they want something, maybe there's a train in town. No way to get through to my store, not while the train's coming through. Likely as not they'll just give up and go home. And an ice cream cone is not like a piece of hardware. A hammer people will buy next trip; they'll never buy an ice cream to replace the one they didn't buy last trip. This whole town can just barely support one store like mine; half a town can't."

Dr. Brown, one of the town's two MDs, is also worried: "One of these days there's going to be a medical emergency, a fire, something like that, and help won't be able to get through. Then there'll be hell to pay. The town just has to face up to it: we have to raise money to construct an underpass."

Mothers are especially critical of the trains. Mrs. Ellen Glasgow says, "These trains are a danger to children. The right-of-way isn't fenced, and trains come through town at thirty miles an hour. Right through our backyards, really. Children don't know enough to keep out of the way. Two dogs were killed last year. Someday it'll be a child."

The president of the railroad says, "People need this coal, and the railroad is the cheapest way of getting the coal to them. Rural City grew up where it is because of the railroad. It would be easier and cheaper to move the town than to relay the tracks."

Answer the following questions on a separate sheet of paper.

1. Name at least three costs the people of the town incur due to the increased use of the railroad.

2. Are the buyers of the coal paying all the costs of supplying it?

3. What do you think should be done in this situation, if anything?

Windmill

The Department of Energy has erected a large experimental windmill. The windmill generates electricity, which is fed to the homes of local residents, but its main purpose is to test windmill designs. The knowledge that will be obtained by operating this windmill will enable people to build less expensive, more durable wind generators in the future.

But the people who live nearby complain.

"That windmill is the ugliest thing I ever saw," says Bill Hetherow. "It looks like a plane crashed up there. That's not what these mountains are about. If God wanted a windmill up there, he'd 'a put it there."

Other neighbors complain that the windmill is noisy when it is operating.

"Noise isn't the half of it," says Maureen O'Leary. "That machine's cracked two of my best china cups. I can just feel the rumble when it gets going." Engineers testing the machine agree that it does generate subsonic frequencies which might crack glass at a distance.

"That's one of the bugs we're working out," they say.

Answer the following questions on a separate sheet of paper:

1. Describe at least three costs people living near the windmill incur as a result of its operation.

2. Who benefits from the operation of the windmill? What benefits do they obtain?

3. What do you think should be done in this situation, if anything?

Wood Smoke

Mercer is a beautiful town in a rural mountain valley. Many people have come here to live just because of its beauty, including many retired people.

Because the prices of other fuels have increased, in the last five years many people in Mercer have started to use wood as their main home-heating fuel. However, smoke from the area's many fireplaces and wood stoves has created an air pollution problem. Now a blue haze hangs over the valley all winter long.

At first, people didn't want to admit the haze was caused by burning wood. Now they are asking the city council to pass ordinances limiting the amount of wood a home can burn.

Part of the problem is esthetic. The mountain peaks that ring Mercer can no longer be seen.

Health is involved, too. Infants and old people are especially affected. Doctors have advised older people with lung problems to leave Mercer. Even people who have lived in Mercer all their lives are being forced to sell their homes and leave.

Answer the following questions on a separate sheet of paper:

1. What costs are the old people who stay incurring as a result of wood-burning? What costs are the old people who move incurring?

2. What costs does wood-burning in Mercer put on a middle-aged person who heats his home with an electric heat pump?

3. What benefits are people getting from wood-burning?

4. If an individual burns less wood, can he or she be sure of suffering less from air pollution? Explain your answer.

5. What do you think should be done in this situation, if anything?

Reactor

Jake Holburn owns a little resort in an isolated rural section of the state. It includes cabins on a lake with a dock and boats. Jake's place is a clean, pleasant, family-style resort. His regulars have been coming back year after year for almost as long as Jake has been in business. That is, until about two years ago.

Jake's resort is a little more than a mile from a nuclear power plant. In fact, the cooling towers of the plant are plainly visible in a photo on Jake's brochure, rising up behind the hills on the other side of the lake.

Jake says, "My business started falling off right after Three Mile Island. I couldn't figure it out. People were even calling canceling reservations—families that had been coming for years. So finally I called up some customers I knew really well, and they told me why they weren't coming."

Mrs. Lucinda Consuelo says, "We've gone to Jake's for about five years and we were very pleased with it. But after hearing on the TV about them evacuating children—when they had that accident in Pennsylvania—and all that stuff, we decided, why take a chance? What if we were at Jake's when something happened? There are plenty of resorts where we can go. Why take the chance?"

Jake says, "I don't know who's right and who's wrong in this nuclear thing. All I know is, I didn't do anything, and I'm going out of business."

Answer the following questions on a separate sheet of paper.

1. What cost is Jake paying?

2. Who benefits from the reactor?

3. Who benefits from the spread of information via TV?

4. Does the spread of accurate information create costs? Does the spread of inaccurate information create costs?

5. What do you think should be done in this situation, if anything?

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External Costs of Energy Supply

Each of the paragraphs below describes a cost related to supplying energy. You are to decide whether each of the costs is an **internal cost** or an **external cost.**

An **internal cost** is a cost the energy user pays. The cost may have first been paid by the energy supplier, but the supplier passes this cost on to buyers as part of the purchase price, so the user of the energy ends up paying the cost.

An **external cost** is a cost that the user does not necessarily pay. Suppliers don't pay it, and it is not passed on to users.

Number the lines on a separate sheet of paper from 1 to 20. After each number, write "Internal" or "External" to indicate whether the cost is paid by the user of the energy or by someone else. Then describe the cost in a word or phrase. An example is done for you.

1. A coal-burning boiler used to heat an office building produces smoke which soils the brick walls of nearby buildings. The owners of these nearby buildings pay to have them steam-cleaned every seven years.

Answer: 1. External. Cost of cleaning buildings.

2. An oil company spends several million dollars in wildcat drilling. They don't find anything.

3. Acid water draining from an old coal mine has killed all the fish in a stream. In that stream, sport fishermen used to catch about 700 pounds of fish a year.

4. In the 1940's, due to air pollution, a small town downwind from a generating station has a higher rate of respiratory disease than a similar town upwind. As a result, more workdays are lost in the downwind town, and people tend to die younger.

5. A worker installing a solar collector falls off the roof and breaks her leg. She is laid up for three weeks; however, her company (by law) carries worker's compensation insurance that pays all her medical bills. The company also has disability insurance that pays her wages while she can't work.

6. Three coal miners are killed in a mine explosion.

7. Suppose carbon dioxide released by burning fossil fuels causes a warming of the earth. The midwestern corn belt becomes a desert, but vast new areas of Canada and Russia become productive wheatlands.

8. A utility purchases a new turbine-generator set.

9. There is a great increase in chainsaw accidents in New England. More people are spending their weekends cutting fuel for winter fires and, partly due to their lack of experience, there are many serious injuries.

10. An accident causes a million dollars' damage to an oil refinery.

Notes

Energy Costs Are Part of the Price of Almost Anything

Why This Lesson?

Students easily recognize that a dollar spent on gasoline has been spent for energy. It is less obvious that we also buy energy *indirectly,* since energy is needed to produce almost every good and service we purchase. This has important consequences. Rising energy costs will tend to raise the prices of everything that embodies that energy. Certain important kinds of conservation—like recycling aluminum, or buying more durable goods—conserve embodied energy. So that we can later develop student understanding of such ideas, we need to give students a chance to reflect on the extent to which energy is needed to produce the goods and services in their lives.

Objectives

Students will give several examples of embodied energy.

Students will describe how suppliers of goods and service recover the cost of the energy they use in providing what they sell.

Materials Needed

bag of carrots or similar consumer good whose process of production is familiar to students.

overhead transparency **Energy Costs for One Gallon of Soft Drink.**

overhead transparency **Energy Costs for an Automobile.**

overhead transparency **Cost of Energy as a Percentage of Value of Shipments in the Ten Most Energy-Intensive Industries.**

worksheet **Goods, Services...and Energy.**

CONDUCTING THE LESSON

Energy Is Needed to Make Things

To provide a focus for a beginning discussion of embodied energy, bring to class some familiar consumer item. In the discussion below, a bag of carrots is used as the example, but any consumer good will do, as long as students are somewhat familiar with how it is made.

Ask the students to give some examples of buying energy. They may mention buying gasoline, paying electric or gas bills—some students may even mention buying energy indirectly, by buying something whose manufacture required energy. If no student gives such an example, point out that it takes energy to make many of the things we buy, and to transport them to us. For example—carrots. Produce the bag of carrots. Did anybody have to buy energy as part of growing these carrots and getting them to the supermarket? What was the energy used for? What was its source? List some of the students' responses on the chalkboard. Responses might include:

Plow and cultivate the fields (probably diesel fuel)

Make the farm equipment (coal, electricity from some source)

Make fertilizer, package it, transport it (natural gas, diesel fuel)

Make pesticides and herbicides, and package and transport them

Apply fertilizer and pesticides (diesel fuel)

Irrigate the field (often, electricity)

Harvest the carrots

Wash the carrots

(Let's not forget the bag the carrots are in.)

Make the plastic

Make it into a bag

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Print it

Transport the bag for the carrots

Transport the carrots from the farm to the store

Conclude this activity by observing that, no matter how many things we list, it is unlikely we'll be able to put down all the different uses of energy that went into getting the bag of carrots to market.

Did this energy cost money? Who bought it? Discuss a few of the responses on the board. How did the people who bought the energy recover their expenses? (ANS: By being paid for their services or goods—ultimately, from the purchase price of the carrots.)

Defining Embodied or Indirect Energy and Energy Costs

Tell the students that the energy needed to provide the carrots is called *embodied* energy. It is energy we buy indirectly, by buying things that required energy to produce.

Energy Is Used in Providing Services

Energy is consumed in providing services, just as it is in providing goods. For example, what are some ways energy is embodied in a high school education?

Transporting students, teachers, books, etc., to and from school

Making desks, textbooks, the school building, films

Maintaining the lawn

Energy used by teachers and other personnel as consumers, at home

Heating the school

Lighting the school

Counterexamples?

Ask, "Can anybody think of anything we do or buy that doesn't require energy to provide?" This gives students a chance to test their ability to recognize embodied energy, by evaluating exceptions proposed by classmates.

Is Embodied Energy Important?

Do we really use very much energy in the form of embodied energy? Is this buying of embodied energy significant compared to our direct purchases of energy, such as when we buy gasoline, electricity, or natural gas?

Let's look at the energy embodied in an automobile. Project the overhead transparency of the automobile. Note that this analysis was done in 1973, and automobiles have changed somewhat since then (the average car now uses less material, but much of the material, like aluminum and plastic, is more energy-intensive than the steel formerly used). Have students interpret a few items to be sure the table is understood.

Point out that the energy is equivalent to that in 993 gallons of gasoline. Is that a significant amount of gasoline? Let students calculate how many fill-ups of a 15 gallon tank that is. It is about a year and a half's worth of gasoline for the average car owner.

Embodied Energy Suggests Conservation Strategies

Project the overhead of energy embodied in a gallon of soft drink. Notice that according to this analysis, the way the drink is packaged makes a big difference in the amount of embodied energy.

How Much of the Price of the Things We Buy Is Embodied Energy?

There is a big difference between the amount of energy needed to produce different goods and services. For example, it takes much more energy to make a dollar's worth of cement than a dollar's worth of legal help.

Put on the transparency **Energy Costs as a Percent of Value of Shipments.** Tell the class that the ten industries shown are those that are the most *energy-intensive* of the major industries, that is, the ones that use the most energy per dollar of goods sold. Make sure the class can read the graph by asking questions like, "If you bought a dollar's worth of paper, how many cents went for energy costs?"

Place embodied energy costs in perspective by noting that while they are significant, other items like labor account for a greater percentage of the value of most goods and services.

Embodied Energy and Your Family Budget

Most people are more interested in the question, How much of the family budget is spent on embodied energy? This is very difficult to figure out. Economists who have tried to do so believe that a typical family spends nearly as much on embodied energy as on energy purchased directly. The higher the family income the greater the percentage of total energy expenditures that is spent on embodied energy.

(Estimates for 1974)

Family income	expenditures on embodied energy =
$1,270	63% of amount spent directly on energy; e.g. utility bills, purchases of gasoline, propane, wood
$11,000	76% of direct expenditures on energy
$30,000	85% of direct expenditures on energy

A Note for the Teacher Only: Embodied Energy and Inflation

Although this needn't be pointed out to the students, you may have heard it said that the increase in the price of energy, particularly oil, was the primary cause of inflation during the '70s. In fact, most economists who have studied this problem believe that energy price increases probably caused only about 2 to 5 per cent of the inflation rate, through their effect on the money supply, while at times the rate of inflation has been greater than 10%. However, the shock of the suddenness of the oil price increases may also have contributed to inflation.

Conclusion: So We're Buying Energy Every Time We Turn Around

You know you are buying energy when you spend money on gasoline at the service station, or pay your electric bill or gas bill. But you're also spending money on energy when you buy almost anything.

Can you avoid spending at least some of this money? That's what we'll look at next.

Homework

An activity sheet, which may be assigned as homework, is provided.

Projects for Independent Investigation

1. Energy costs are a greater percentage of the cost of providing some goods or services than they are of others. For example, fuel costs are a major item for airline companies, but a relatively small part of the cost of running a dental office.

Choose an industry that is important in your town. Study it to determine how sensitive it is to increases in the price of various of energy sources.

Hint: A good source of information on particular industries is the *U.S. Census of Manufactures,* which is available in most public libraries.

2. Make a graph showing a supply curve, a demand curve, and the equilibrium price for a good. Add to the graph to show the effect of an increase in the price of the energy used to produce the good.

3. Is there embodied energy in energy purchases like electricity or gasoline?

In this country, diesel fuel is less expensive than gasoline. Gallon for gallon, diesel fuel contains more energy (Btu's) than gasoline. Some persons (e.g., Smokey Yunick, Popular Science's master mechanic) argue from this fact that we can expect the price of diesel fuel to rise until buyers pay the same amount per Btu whether they buy gasoline or diesel fuel.

However, it takes more energy at the refinery to produce a gallon of unleaded gasoline than it takes to produce a gallon of diesel fuel. From this fact, show why, other things being equal, one would not expect gasoline and diesel fuel to sell for the same price.

Estimated Energy Costs for One Gallon of Soft Drink

	Btu's
manufacturing beverage itself, 3 kilowatt-hours =	9,600
packaging and transportation, if in 12-ounce bimetal cans	
mining (2.5 lbs of ore per pound of finished steel)	1,570
transportation of ore (1,000 miles by barge)	550
manufacture of steel from ore	27,600
aluminum lid (11.9% of total can weight)	12,040
transportation of finished steel (392 miles average)	230
manufacture of cans (4% waste)	3,040
transportation of bottler (300 miles average)	190
transportation to retailer	6,400
waste collection	110
total for packaging and transport	51,730
Grand total	61,330
(For comparison	
packaging and transport, if in all-aluminum cans	69,000
packaging and transport, if in returnable glass bottles	17,800)

Source: Beverage manufacturing, **Environment**, Packaging, Bruce M. Hannon, **Environment**, March 1972.

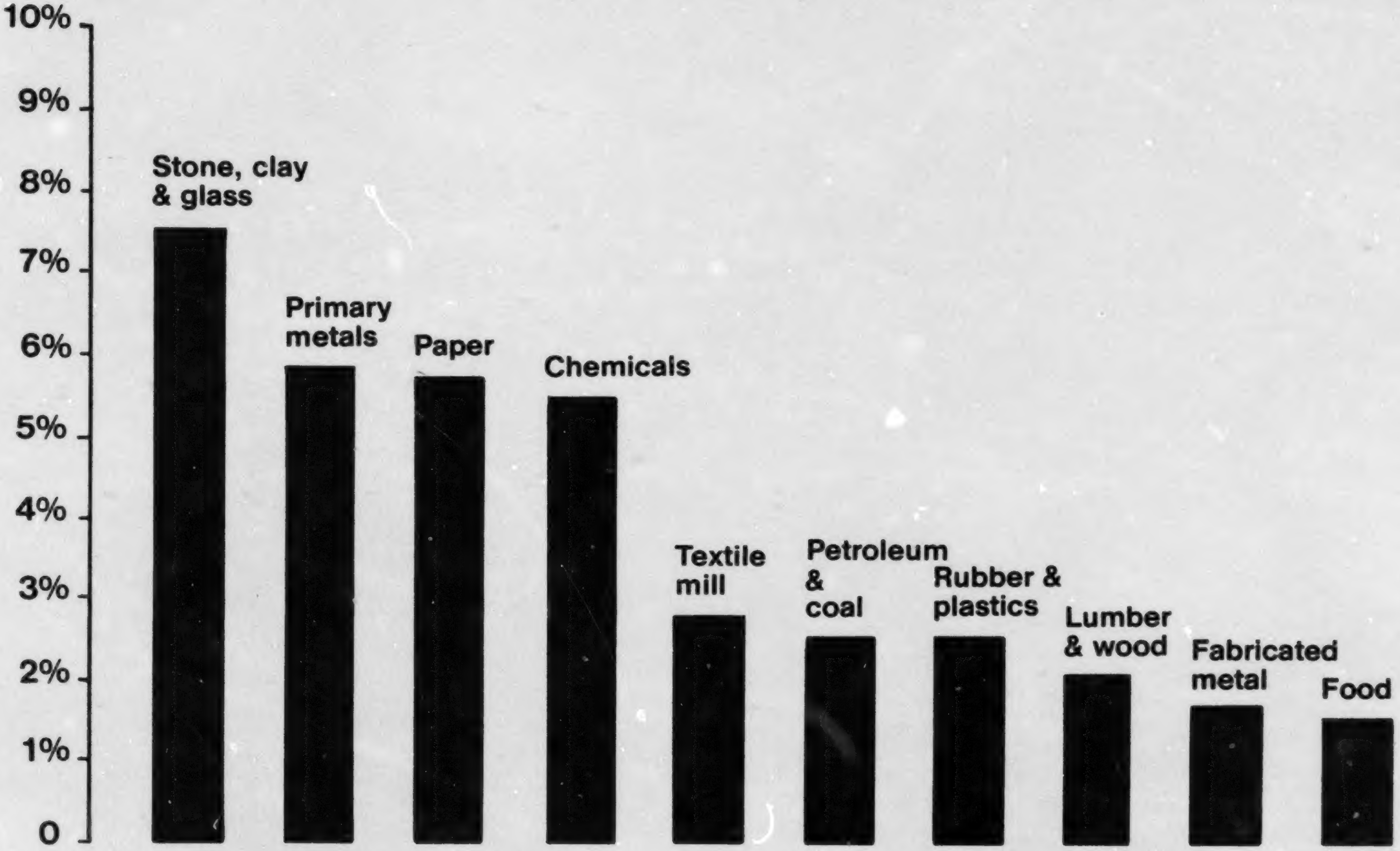
Energy Used to Make a 1967 Automobile

What's in the auto	1000's of Btu's
536 lbs iron castings	6,704
29 lbs steel castings (for engine)	668
1903 lbs cold rolled sheet (for body)	48,252
47 lbs steel wire	3,615
171 lbs steel forgings	1,429
344 lbs other carbon steel	8,082
104 lbs alloy steel	2,577
13.4 lbs stainless steel	491
40 lbs pig iron	481
74 lbs of aluminum	
4.2 lbs forged aluminum	525
37.4 lbs cast aluminum	4,003
26.4 lbs rolled aluminum	3,304
6.4 lbs primary aluminum	716
54 pounds of copper	
6.4 lbs wire	341
2.6 lbs castings	160
44.8 lbs rolled copper	2,864
50 pounds of zinc	
50 lbs of die castings	2,199
1 lb of refinery zinc	34
24 square feet of safety glass	2,169
10 lbs of plastic	133
2 yards of fabric	27
metal powder	368
miscellaneous	238
Stamping sheet steel into body parts	3,615
Fabrication of other parts	13,572
Transporting materials and parts	2,234
Assembling automobile	14,680
Transporting the assembled auto	767
Total	124,248

1 gallon of gasoline can provide 125,000 Btu, so the embodied energy is equivalent to about 993 gallons of gasoline. (A year and a half for the average car.)

Data: R. Stephen Berry and Margaret F. Fels

Energy Costs as a Percent of Value of Shipments in the 10 most energy-intensive industries



Goods, Services ... and Energy

In each line, fill in the empty space. Two examples are done for you. There are many possible right answers.

Good or service you might buy	Embodied energy bought indirectly	Who bought the energy (and passed on the cost)
1. Fill a cavity in a tooth	electricity to run the drill	Dentist
2. One play on an arcade game	electricity used to make computer	Manufacturer
3. Motorcycle	coal to make steel	
4. Hamburger	natural gas to heat grill	
5. Apple	hydroelectricity for irrigation pumps	
6. Cotton shirt	electricity to run the looms	
7. Watch a TV show	diesel fuel to carry the TV to the store	
8. Movie ticket	electricity from nuclear fission for projector	
9. Dungeons & Dragons set	natural gas to melt metal for figurines	
10. Telephone call	electricity from coal	
11. Permanent at hairdresser		hairdresser
12. TV dinner		supermarket
13. TV dinner		food processor
14. TV dinner		farmer
15. Paperbound book		printer
16. Church service	natural gas to heat building	
17. Ticket to basketball game	petroleum to bring the visiting team	

No Way of Saving Energy Is Free

Why This Lesson?

In deciding whether to undertake an energy conservation measure, we balance the costs against the benefits we expect to receive—in the case of consumers, mainly energy costs we expect to avoid in the future. Because the first conservation measures people take are low-cost ones (like turning out the lights), students tend to be most familiar with measures whose costs are so small in comparison to benefits that they seem not to exist, and so doing a cost-benefit comparison seems a waste of time. To show that some method of weighing costs against benefits will be necessary, we must first demonstrate the reality and variety of costs.

Objectives

Students will describe the process of deciding whether to undertake an energy conservation measure in terms of the person making the decisions acting to maximize his satisfaction.

Given any widely practiced way of saving energy, students will identify at least one cost incurred.

Among costs incurred, students will recognize the loss of alternative uses of one's time as a cost.

Format of the Lesson

Announce beginning of new topic: conservation

Elicit examples of energy conservation measures

Point out one benefit: money is saved (future energy costs)

Elicit conservation measures taken in students' homes
Usually few or none. Why?

Describe deciding what measures to take by comparing costs and benefits.

Review the idea of cost

Practice identifying costs, using the activity sheet

Materials Needed

activity sheet **Costs of Saving Energy,** one per student.

CONDUCTING THE LESSON

Introducing the Economics of Saving Energy

Tell the class we are now moving on to a new topic, the economics of energy conservation. What do we mean by energy conservation? Ask the class to name some ways of saving energy. Probably students will name such conservation measures as

Turning out lights
Insulating houses
Insulating water heaters
Buying more fuel-efficient automobiles

Acknowledge that these are actions some people have taken. Why have they done these things? Students may give a variety of answers:

(ANS: To save energy.) Yes, some people put a very high personal value on not wasting energy. They're willing to give up other things to avoid using extra energy.

(ANS: To save money.) Yes, most people do these things because they want to save money. There are other things we would like to do with the money we are now spending on energy.

In all these cases, people are expecting to get something they want out of what they do. Economists call these **benefits.** Most of the things people do they do because they expect to receive benefits.

Deciding How to Save Energy

Let's suppose someone decides they want to save energy. Do they immediately do all the things we've named, and all the other things that save energy that we haven't named? (ANS: No.) No, they can't. Nobody can. They have to decide what to do first with the time and money they have available.

Your families, like all families, would like to save money. Let's see what we've actually done, by having a quick show of hands.

How many people have insulated their water heater?

How many people have cars that get over 30 miles per gallon?

How many people live in buildings that they are certain have the recommended amount of insulation?

We're like most people. Most of us haven't done many of the things we could do that would cut our energy costs. Why not? Is it because we're crazy? Well, I suspect something like this happens: your mom stands there and wonders, do I want to go to the lumber yard and spend $15 on insulation for the water heater, or do I want to spend the $15 on taking the family to the movies? Or your dad thinks, do I want to go fishing this weekend or do I want to caulk the house? Or the family looks at automobiles and agrees that it would be nice to have lower gasoline bills with a small car but you feel you need a bigger car to hold the whole family at once.

So we're not crazy. We pick the thing we'd rather have. People have to make choices and, when they make choices, they're giving up something, like the movies or going fishing or lowering their gas bills. They might make a different decision if they had better information, or with hindsight they might wish they had made a different decision, but they're not crazy. It's a rational process. They are comparing **costs** with **benefits.**

In deciding which energy-saving steps to take first, people subtract the costs they expect to incur from the benefits they expect to get, and they do the things that they expect will give them the greatest **net benefit.**

Just because you compare costs and benefits doesn't mean you will always do the right thing. How can you go wrong? One way is by not recognizing all the costs. For example, a person might underestimate the costs of insulating the walls of her house—just like people have sometimes underestimated the costs of building a new power plant. Another kind of mistake is not recognizing all the benefits. Underestimating benefits might lead someone to fail to do something that would have saved him more money than anything else he could have done. For example, many people with uninsulated attics just don't realize how much even a little insulation could reduce their heating bills. They are underestimating a benefit.

So a key to making the most effective use of your time and money is being able to recognize costs and benefits. Today, we will learn to recognize some of the kinds of costs people incur in saving energy. Later we will look at the benefits they get.

Reviewing the Concept of Costs

If your class has completed the lessons in Section 3 involving suppliers' costs, students should be familiar with the idea of cost. If not, point out that, although it's true that paying money for something is evidence that a cost has been incurred, costs are often incurred without money changing hands. Whenever we make a decision that involves our giving up something, we incur a cost. For example, whenever we, ourselves, do anything, one of the costs is whatever else we might have done with our time.

Ask the students what it costs a family to send a child to school? In the discussion, point out that one of the costs that used to be very important in this country, and still is in many parts of the world, is the loss of the student's labor. That boy or girl could be pulling weeds on the family farm or feeding the chickens; not doing those chores is a cost to the family. So costs are not always obvious. Sometimes it isn't easy to put a dollar value on a cost.

Practice in Applying the Idea

Pass out copies of the worksheet. Do the first few examples in class. Discuss the answers. Ask students to complete the remaining items as homework.

Projects for Independent Investigation

1. One of the best booklets of energy-saving tips is titled "Energy Savers: Low-Cost No-Cost." Explain why there is no such thing as a "no-cost" energy conservation measure.

2. Some builders say that the longer you expect a new house you are building to last, the more insulation it should have.

Do you agree, and why or why not? (Hint: Does it make sense to insulate a house that will be torn down next year?)

3. A book of advice to homeowners says, "The object of insulating is to reduce heating loss to the lowest possible value." From an economic point of view, why is this statement wrong?

Answers and Background Information for the activity sheet *Costs of Saving Energy*

1. Purchase price of the insulation.
Wages paid the installers or the fee paid the contractor, or what the owner might have done with the time he or she spent doing-it-himself/herself.
Inconvenience suffered by living in the home while workers are insulating it.

2. Increased cost of buying and operating larger refrigerator needed to store perishables for a longer period of time.
Increased time and aggravation of planning a whole week's needs.
Loss of opportunities to see and visit with friends and neighbors.

3. Purchase price of solar heater.
Installation costs of solar heater.

4. Purchase price of stove.
Loss of pleasant sight of the fire.

5. Cost of new fixtures.
Cost of heat from another source to make up for the heat that used to be supplied by the incandescents (if it's winter and the room is being heated).

6. Bus fare.
What you might have done with the time spent waiting for the bus.

7. Purchase price of the new car.
Perhaps, difference in price of leaded regular and unleaded gasoline.

8. Labor of flicking the switch.
Wear and tear on switch.

9. Increased purchase and cleaning costs of heavier clothes, blankets.

10. Purchase price of new range.
Time spent waiting for ignitor to work.

11. Purchase price of insulating blanket.
Loss of space near heater due to heater's increased bulk.

12. Cost of tune-up.
Loss of use of car during tune-up.
Loss of time delivering and picking up car, or waiting for it.

13. Increase in money spent on shoes due to increased wear.
Loss of time.

14. Purchase price of new house.
Moving expenses.
Cost of becoming familiar with new neighborhood, school etc.

15. Capacity of old factory.

16. Loss of whatever else you could have done in the time spent collecting and turning in cans.
Cost of water to rinse cans.
Cost of boxes or bags used to hold cans.
Gasoline and wear on car used to transport cans to recycling center.

17. Purchase price of caulking and weather stripping.
Other things you might have done with your time.
Risk of injury.

18. Purchase price of refrigerator.

19. Physical discomfort at higher temperature.
(A benefit in addition to saving electricity: increased service life of air conditioner.)

20. Serviceperson's charge for tuning furnace.
Perhaps purchase price of new filter, parts.

Costs of Saving Energy

Take a piece of ruled paper. Number the lines from 1 to 20.

Below is a list of 20 ways of saving energy. For each way of saving energy, write down a cost that would be incurred. (Some of the costs may be things it isn't easy to set a dollar value on.) Many different answers are possible.

Remember, just because taking an action involves incurring a cost does not mean that action isn't a sensible thing to do. The savings may far outweigh the costs.

1. Save heating oil by insulating your home.
2. Save gasoline by doing all your grocery shopping in one weekly trip.
3. Save natural gas by converting a school's swimming pool heater to solar.
4. Save wood by replacing an open fireplace with a modern wood stove.
5. Save electricity by replacing your incandescent lights with fluorescents.
6. Save gasoline by taking the bus.
7. Save gasoline by trading in your old gas guzzler for a new car that gets 40 miles to the gallon.
8. Save electricity by turning off the light when you leave the room.
9. Save natural gas by turning down the thermostat in your home.
10. Save natural gas by buying a new kitchen range with electronic pilotless ignition.
11. Save natural gas by insulating your old water heater.
12. Save gasoline by getting your car tuned.
13. Save gasoline by walking to work.
14. Save gasoline by moving to a home nearer the place where you work.
15. Save natural gas by replacing an old glass factory with a new one that uses less energy.
16. Save electricity by recycling aluminum cans.
17. Save heating oil by spending a weekend caulking and weather stripping your home.
18. Save electricity by buying a more energy-efficient refrigerator.
19. Save electricity by turning up the thermostat on your air conditioner.
20. Save electricity and heating oil by getting your oil furnace tuned.

Unit Eight
Conservation

Fairness

The great novelist Leo Tolstoy expressed the feelings of many people when he wrote that it is "a shame to use for one's own pleasure what another person needs to live."

1. Do you agree with Tolstoy? Why or why not?

2. Think of an example of using energy for pleasure. Think of another example in which the same energy source is used to provide something someone needs to live.

3. Does the "pleasure" use really lessen the amount of energy available for the "necessity" use? If you think so, describe exactly how the two would be connected.

4. Suppose there is a shortage of diesel fuel. Farmers will be unable to plant all their cornland. The government could allocate the available fuel to farmers (taking it away from, say, truck drivers). Do you think that is the right thing to do?

5. Suppose most of the corn raised will be exported. Would that change your opinion?

6. Suppose must of the grain will be fed to pigs and cows. Would that change your opinion?

7. Some people have suggested that, because the United States is a wealthy nation, it should concentrate on developing energy sources that require a lot of expertise and capital to get started, such as solar and nuclear energy. That would leave the petroleum, which can be used in cheap equipment and with relatively little knowledge, to the world's underdeveloped nations.

What do you think of this idea? Discuss it in terms of economics and then in terms of ethics.

This Is the Big Payoff!

In this project, you will try to figure out the **best** way for your family to lower their energy bills. Pretend you have some money to spend on home insulation, a new car, a flow constrictor for the shower, or anything else. You will make five separate reports, pretending you have $10, $100, $500, $2,000, or $10,000 to spend. In each of the five reports, tell:

1. What you would do. You can do more than one thing, as long as the total costs don't exceed the available dollars.

2. How much it would cost. Try to include names of suppliers who would really sell you the material and what their prices are. You may include ads if you want.

3. How it works.

4. How much energy you would expect to save. Include all your calculations. For example, if you are going to put storm windows on your house, we would want to know how many square feet of windows you had, how many Btu's you estimated were lost through those windows in a winter, and how much you expected supplying those Btu's would have cost each year for the life of the storm windows.

5. What the payback period would be.

These reports will not be due for many weeks. This will give you a chance to think about them while we are studying different ways people can conserve energy.

You may get all the help you want from anyone you wish in thinking about this project, but you must write the reports all by yourself.

Your reports will be graded on:

1. How much money you can save for every dollar you invest.
2. How convincing your calculation of savings is.
3. The ingenuity you show in finding the best solution for your particular family.
4. How complete and accurate the figures backing up your estimates are.
5. How well you have researched what's available.
6. The clarity and neatness of your presentation.

Good luck!

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Out the Windows!

In this exercise, we will estimate how much heat your home loses by conduction through its windows during a typical heating season, and how much that heat costs. First, we need to know the number of degree-days of heating in your locality. It is ______________________________ degree-days.

Different kinds of windows lose heat at different rates. Below are some R-values typical of different kinds of windows. If you're not sure of the size of the air space, guess.

Go around your home with a ruler and measure the size of the glass in each window. (144 square inches = one square foot). Your teacher may be able to give you some forms to help you do this. Add up the square footage of all the windows of each type and enter them in the table below. Divide by the R-value. Total the results. You now know how many Btu would be lost in one hour through all your windows if there was one degree Fahrenheit difference between inside and outside. To find heat loss for the year, multiply by 24 (hours in a day, to get loss in a day) and by the number of degree-days.

Total square footage of all windows of this type

R-value which is

$$\frac{\text{area in sq. ft. X hours} \times \text{(difference in temperature of inside \& outside surface)}}{\text{Btu that get through}}$$

Window Type					
Single glass	________ sq. feet	÷	0.88	=	________
Double glass, 3/16" air space	________ sq. feet	÷	1.49	=	________
Double glass, 1/4" air space	________ sq. feet	÷	1.64	=	________
Double glass, 1/2" air space	________ sq. feet	÷	1.73	=	________
Double glass, 3/4" air space	________ sq. feet	÷	1.82	=	________
Single glass with storm window	________ sq. feet	÷	1.89	=	________
Double glass with storm window	________ sq. feet	÷	2.65	=	________
			TOTAL		________

________ degree-days x 24 hours in a day x ________ = ________ Btu's lost

This is the total number of Btu's lost by conduction in one heating season.

Notes

Insulation Where We Don't Want It

Insulation slows down the flow of heat. In the cold winter, insulation keeps heat inside the house from flowing to the outside. In the summer, it slows down the flow of outside heat into the house.

But sometimes we want heat to flow as fast as possible! We don't want to insulate. Check for these kinds of unwanted insulation in your home.

1. Every refrigerator has a coil. Usually it is in the back. Sometimes it is underneath. A fluid flowing through the coil carries heat from inside the refrigerator to the outside. So we want heat to escape from the coil as fast as possible.

The coil is usually painted black. Why?

Coils get dusty. The dust is an insulator that slows down the circulation of air around the coil. That makes the refrigerator less efficient.

If your refrigerator's coil is dusty, dust it off. A paint brush is excellent; a vacuum attachment works too. Be careful not to bend or damage the coil.

2. Is your home heated with radiators? Steam or hot water circulates through a radiator. The heat travels from the radiator to the things in the room by conduction and radiation. Some electrically heated homes use baseboard radiators.

Is your radiator insulated by dust? Fix it up.

3. Every air conditioner has a coil. Like the coil on a refrigerator, the air conditioner's coil exhausts heat taken from inside into the outside air. We want this heat to flow as fast as possible.

With the help of a family member, check the coil of your air conditioner or heat pump. Is it free of dust?

While you're at it, check to see whether direct sunlight can strike the coil. Why is this bad? What could you do about it?

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Instructions to the Computer

Imagine that there is a computer in your house. This computer is connected to every electrical switch in the house, so that it can turn any light or appliance on or off. It is also connected to the furnace and air conditioner. It has a built-in clock that tells it what time, day of the week, and date it is, and it has a gadget in each room that tells it whether there is anybody in the room. (But it can't tell the difference between a dog and a person). It can tell the temperature outside and the temperature in each room inside.

You want to use this computer to save energy in your house. What instructions will you give it? (You can also add extra ways of getting information to the computer if you want.)

To help you get started, here are half of two sample instructions. You can complete and use them.

1. If nobody is in the room, then ____

____.

2. If it is between 9 p.m. and 6 a.m. and there's nobody in any room except the

bedrooms, then ____.

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